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A Study on the Effects of Selected Micronutrients, Locations, and Their Interaction on Cassava Yield Based on the Two-Way ANOVA Model with Interaction

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Abstract. *The paper investigated the effects of fertilizer (Zinc, Iron and Manganese), location of farm land and their interaction on cassava yield. The secondary data used for the study were collected from the National Cereal Research Institute of Nigeria Outstanding Farm, Nung Udo, Uyo, Akwa Ibom State. The data comprised of cassava yield (Hectares) for 2016 planting season, five separate farms where three types of fertilizer were applied. The two-way analysis of variance (ANOVA) technique with interaction was used in the analysis of the data. Furthermore, the Tukey HSD test was conducted to compare the treatment means. The result of the study showed that there is significant mean difference in the yield of cassava based on the three types of fertilizer applied. On the basis of farm locations, the result shows that there is no significant mean difference in cassava yield while the interaction between fertilizer and farm location affects cassava yield significantly at 5% level of significance.*

Keywords: *two-way analysis of variance with interaction; Tukey test; fertilizer; cassava yield; farm location*

1. INTRODUCTION

Cassava (*manihot esculentus*) is a dicotyledonous crop that originated in Latin America about 4000 years ago [1]. It is a staple as well as a cash crop. Different parts of the cassava crop are used for different purposes. For example, cassava leaves are a source of protein, vitamins, and minerals [2]. They constitute a powerful antioxidant for preventing cardiovascular disease, stroke and cancer and play a key role in vitality and metabolism. The leaves also contain Iron and Zinc [3,4,5]. Cassava roots are edible and can be processed in different ways to obtain different products, among which are cassava flour, chips and pellets, garri and starch. Cassava also serves as an industrial raw material for production of starch, ethanol, bio-fuel, thickening agents, gravies, glucose, bread, pasta, couscous, animal feed, adhesives, pharmaceutical, gums, confectionaries, yeast and livestock feed [6,7,1].

Nigeria is one of the cassava-producing countries in the world. The origin of cassava in Nigeria is dated back to the sixteenth century [8]. In recent times, Nigeria was rated the highest producer of cassava [9,5]. Despite its position in terms of cassava production globally, majority of cassava produced in Nigeria are consumed locally [10]. It is well known that Nigeria has a

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fast-growing population. As a consequence, increased cassava production is essential in meeting the needs of the people pertaining to food, food security, employment and income generation through the export of cassava products.

In view of the importance of cassava, several studies have been performed to determine factors that affect its production. Cassava, just like other crops, require certain nutrients in the soil for survival and optimal yield. The extent to which the nutrients are available in the soil determines the fertility of the soil. Hence, soil fertility is one of the factors of interest in cassava production. Low soil fertility often results in low cassava productivity if it is not being remedied [11,12] . One way of remedying the problem of low fertility of soil is to apply fertilizer the soil. Fertilizer application is one factor that can increase the yield of cassava [13,14,15]. Inorganic fertilizers usually comprise nutrients. The nutrients are of two types, namely macronutrients and micronutrients. The well-known NPK fertilizers contain the macronutrients such as nitrogen, phosphorus and potassium. Though these fertilizers are widely used to enhance soil fertility, there are situations where inorganic fertilizers comprising micronutrients like iron (Fe), manganese (Mn) and zinc (Zn) are needed by cassava crops [16,17,18]. Other factors affect cassava yield have been established in the literature. They include diseases, unfavorable agro-climatic conditions and cassava crop varieties affect [19,20].

Some researchers assessed the role of farm sites (locations) in cassava productivity. In particular, Sarr et al. [21] conducted a study to determine the growth characteristics of improved and local cassava varieties in eastern Cameroon, based on repeated cultivations. They also examined the effects of different soils on cassava growth. In the course of their study, they generated data over two planting seasons and carried a two-way ANOVA for data pertaining to each season. The results obtained in their study showed that variety and sites significantly affected growth of cassava and there were no significant interactions between variety and sites. In another study, Biratu et al. [22] conducted an experiment to investigate the effect of chicken manure on cassava root and biomass yield at Kabangwe and Mansa, two locations representing agroecological zones II and III, respectively, in Zambia. The treatments used in the experiment were four levels of chicken manure (0, 1.4, 2.8, 4.2 ton/ha) and a single level of NPK fertilizer applied at 100N-22P-83K kg/ha. The randomized complete block design (RCBD), with three replications was adopted in the study.

The results corresponding to the research indicated significant ($p < 0.05$) treatment effects on cassava root yields at both sites. From the foregoing, it is crystal clear that a number of studies deals with the effects of each of fertilizers and farm sites (locations) on cassava yield. To the best of our knowledge, none of the studies is concerned with examination of the interaction effects of both factors on cassava production. Also, we have not been able to see any work that compare the effects of zinc, iron and manganese fertilizers on cassava yield. This study addresses these and related issues by analyzing data on yields of cassava corresponding to zinc, iron and manganese fertilizers and five different locations using a two-way ANOVA model with interaction. The remaining part of this study is structured as follows: Section 2 is based on the data source and methodology. In Section 3, we present the results obtained by analyzing the data and Section 4 contains the conclusion of this study.

2. MATERIALS AND METHODS

The data used for this study are secondary data on cassava yields, which correspond to a two-factor experiment with four replicates. The data were collected from the National Cereal

Research Institutes of Nigeria (NCRIN) Outstanding Farm, Nung Udo, Uyo in Akwa Ibom State. Fertilizer and location were the factors considered in the experiment. In particular, three types of fertilizers, namely, Zinc (ZN), Iron (Fe) and Manganese (Mn) fertilizers were adopted. Also, five different locations L1, L2, L3, L4, L5 comprising loamy sand (LS), sandy loam (SL), sandy clay (SC), sand, clay and loam (SCL) and an organic compound (OC), respectively, were given due consideration. In view of the nature of the data, the two- way ANOVA technique was primarily used to analyze the data. In what follows, the method and the accompanying procedures are discussed.

2.1 Methods of Analysis

2.1.1 Two-Way ANOVA

Analysis of variance is a well-known statistical procedure for analyzing data generated in the course of comparative experiments. It is worthy of note that different experimental situations require different analysis of variance models. Here, we have data from a two-factor experiment that can be analyzed using the fixed effects two-way ANOVA model with the interaction term:

$$Y_{ijk} = \mu + \alpha_i + \beta j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \text{ for } \{i = 1\ldots3 \; j = 1\ldots5 \; k = 1\ldots4 \qquad (1)$$

where

Y_{ijk} = The observation associated with ith level of factor A (Fertilizer), j^{th} level of factor B (farm location), and kth replicate,

μ = The overall mean,

α_i = The main effect of the i^{th} level of fertilizer,

β_j = The main effect of the jth level of farm location effect,

$(\alpha\beta)_{ij}$ = The interaction between i^{th} level of fertilizer and j^{th} level of farm location and ε_{ijk} are IID N $(0, \sigma_e^2)$ random variables.

In the next section, we shall use the method proposed by (1) to test:

H_0 (1)**:** $\alpha_i = 0$ (There is no significant mean difference in the yield of the cassava based on the three types of fertilizer applied) against H1 (1): $\alpha i \neq 0$ (There is a significant mean difference in the yield of the cassava based on the type of fertilizer applied),

H_0 (2)**:** $\beta_j = 0$ (There is no significant mean difference in the crop yield from the five farm locations) versus

H_1 (2)**:** $\beta_j \neq 0$ (There is a significant mean difference in the crop yield from the five farm locations) and

H_0 (3)**:** $(\alpha\beta)_{ij} = 0$ (There is no significant mean difference in the interaction between fertilizers and crop) against

H_1 (3)**:** $(\alpha\beta)_{ij} \neq 0$ (There is a significant mean difference in the interaction between fertilizers and crop.

The information in Table 1 is useful in testing the hypotheses.

SS_T (Sum of Squares due to Total) $= \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{r}\left(Y_{...} - \overline{Y}_{...}\right)^2,$

SS_A (Sum of Squares due to Factor A) $= rb \sum_{i=1}^{a} (\overline{Y}_{i..} - \overline{Y}_{...})2,$

SS_B (Sum of Squares due to Factor B) $= r \sum_{i=1}^{b} (\overline{Y}_{.j.} - \overline{Y}_{...})2,$

SS_{AB} $= r \sum_{i=1}^{a} \sum_{j=1}^{b} (\overline{Y}_{ij.} - \overline{Y}_{i..} - \overline{Y}_{.j.} + \overline{Y}_{...})2,$

SS_E (Error Sum of squares) = SST - SSA - SSB - SSAB,

Table 1. ANOVA table for two-way analysis of variance with interactions

Source	Sum of squares	Degree of Freedom	Mean Sum of Squares	F - ratio
Factor A	SS_A	$a - 1$	$\frac{SS_A}{(a-1)}$	$F_1 = \frac{MSS_A}{MSS_E}$
Factor B	SS_B	$b - 1$	$\frac{SS_B}{(b-1)}$	$\frac{MSS_B}{MSS_E}$
Interaction	SS_{AB}	$(a-1)\times(b-1)$	$\frac{SS_{AB}}{(a-1)\times(b-1)}$	$\frac{MSS_{AB}}{MSS_E}$
Error	SS_E	$ab(n-1)$	$\frac{SS_E}{ab(n-1)}$	
Total	SS_T	$N - 1$	$\frac{MS_E}{(N-1)}$	

where

a = number of levels of factor A,

b = number of levels of factor B,

r = number of replicates

n = abr,

Y_{ijk} = the elements in the groups,

$\overline{Y}_{ij.}$ = nean of the replications,

$\overline{Y}_{i..}$ = the mean of factor A,

$\overline{Y}_{.j.}$ = the mean of factor B, and

$\overline{Y}_{...}$ = the total mean factor A and factor B.

At level of significance, we reject H_0 (1) if $F_1 > F_{0.05, a-1}$, ab(n-1) and accept it if otherwise. If $F_2 > F_{0.05,\ b-1}$, ab(n-1), we have sufficient evidence to reject H_0 (2). Again, it is reasonable to reject H_0 (3) whenever $F_3 > F_{0.05,\ (a-1)(b-1)}$, ab(n-1), where $F_{\alpha,u.v}$ is the upper percentage point of the F distribution with the numerator and denominator degress of freedom equal to u and v respectively.

2.1.2 Necessary Test for the Two-Way ANOVA

The two-way ANOVA model with the interaction term, just like other statistical models, is applicable when certain assumptions hold. Several statistical tests have been introduced with a view to checking whether the data or the residuals from the fitted ANOVA model satisfy the required assumptions. Among the keys are the normality and constant variance assumptions According to Heckard and Utts [23], the assumptions of two-way analysis of variance with interaction are that the samples are random samples drawn from independent normally distributed populations with constant variance. Consequently, we proceed to discuss the normality and equality of variance tests.

a. Normality Test

The Anderson-Darling test is often used to test if the given data follow a specific distribution, especially the normal distribution [24]. In testing for normality of data using this procedure, we consider the null and alternative hypotheses H_0: The population is normally distributed and H_1: The population not normally distributed respectively. The requisite test statistic is [25]

$$A^2 = -\ N\ -\ S, \tag{2}$$

$$S = \sum_{i=1}^{N} \frac{2i-1}{N}\left[\ln ln\left(F(y_i)\right)\ +\ ln(1\ -\ F\left(y_{n+1-i}\right))\right]. \tag{3}$$

F = cumulative distribution function of the specified distribution and y_i are the ordered data. We reject H0 if A2 is greater than the critical value. Otherwise it is not rejected.

b. Equality of Variance Test

A number of test procedures for testing homogeneity of *a* population variances are available in the literature on statistical science. The Bartlett's test is quite popular among these tests and it is applied in this study. In this test, the null hypothesis and alternative hypothesis of interest are:

H_0: The variances are equal and H_1: The variances are not equal respectively. Again, its related statistic has the form [26,27]:

$$T = \frac{2.3026\left[(N-a)Sp^2 - \sum_{i=1}^{a}\left(n_i-1\right)S_i^{\ 2}\right]}{1+(3(a-1))^{-1}\left(\sum_{i=1}^{a}\left(n_i-1\right)^{-1}-(N-a)\right)}, \tag{4}$$

where

$$Sp^2 = \frac{\sum_{i=1}^{t}\left(n_i-1\right)S_i^{\ 2}}{N-t},\ S_i^{\ 2} = \text{sample variance associated with the i}^{\text{th}}\text{ population, i=1, 2, …, } a, \tag{5}$$

S_i^2 = variance of the *ith* group,

t = number of groups.

N =total number of observations,

S_p^2 = Pooled variance and n_i is the i^{th} sample size.

Given that $\chi^2_{\alpha,a-1}$ is the upper α percentage point of the chi-square distribution, the null hypothesis of equal population variance is rejected whenever $T\ >\ \chi^2_{\alpha,a-1}$. Alternatively, we reject H_0 if the *p*-value is less than 0.05 (level of significance). Otherwise it is accepted.

2.1.3 Multiple Comparisons

When an analysis of variance result indicates that row, column or the interaction effects are significant, it is necessary to make comparisons among the row, column or the interaction means to discover the specific differences. The multiple comparison method is useful in this regard.

a. Turkey HSD Test

It is a popular method of making all possible pairwise comparisons among group of means [28,29]. It is a post-hoc test based on studentized range distribution. It is used to find the means that are significantly different from each other. It is used in making all pairwise comparison of means of k groups. The test is based on the assumptions that observation is independent within and among groups and that the group for each means in the test are normally distributed and having equal within group variance. In this test, we test the null hypothesisH_0: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$(distribution underlying the samples all have the same mean) against the alternative hypothesis H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \ldots \neq \mu_k$ (distribution underlying the samples have different mean) using the statistic:

$$q_s = \frac{|\bar{X}_i - \bar{X}_j|}{\sqrt{\frac{s_w^2}{n}}}, \tag{6}$$

where q_s = sample test statistic, $\bar{X}_i$, $\bar{X}_j$ are the two means been compared, n = size of each of the group, S_w^2 =within group variation, q_t =value obtained from the studentized range distribution table. If $q_s \geq q_t$, we reject H_0 and conclude that the two means are significantly different at α level of significance($0 \leq \alpha \leq 1$).

3. RESULT AND DISCUSSION

In order to apply the homogeneity of variance test, it is necessary to establish that the data are normally distributed. Hence, we apply the Anderson-Darling test to the data. Figure 1 contains the Anderson-Darling Normality probability plot, the value of the associated statistic and p-value. It is easily observed that the data are normally distributed, as the p-value exceeds the significance level of 0.05. It can be observed from the results in Figure 1 that the calculated value of the statistic is 0.422. Comparing this value with the critical value 0.787, we also arrive at the conclusion that the data are normally distributed.

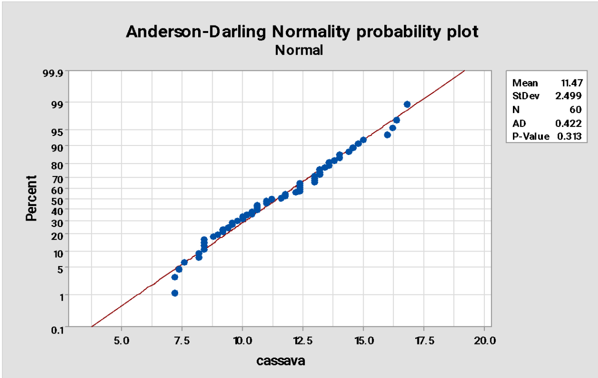

Figure 1. Anderson-Darling normality probability plot

The p-value for Bartlett's test for homogeneity of variance is shown in Figure 2, with a *p-value* = 0.985, which is greater than 0.05 (level of significance), it becomes necessary not to reject the null hypothesis that the population variances are equal. Having observed that the data satisfy both the normality and constant variance assumptions, we proceed to present in Table 3 the results of the two-way ANOVA with interaction that correspond to the given data.

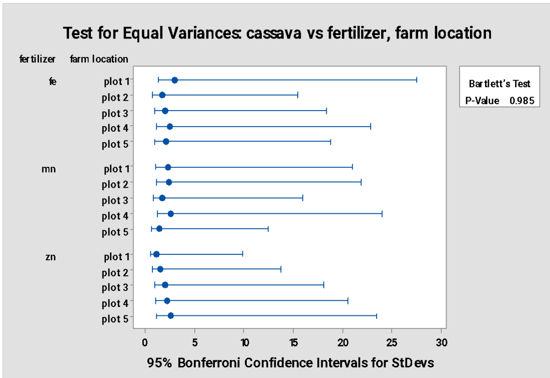

Figure 2. Bartlett's test for homogenity of variance

In accordance with 5% level of significance and p-values, Table 2 reveals no sufficient evidence in support of the acceptance of H_0 (1) and H_0 (3). We then conclude that there is a significant mean difference in the yield of the cassava based on the three types of fertilizer. Consequently, there is also a significant mean difference in the cassava yield due to the interaction between fertilizer and farm location. On the other hand, we fail to reject the null hypothesis H_0 (2), which implies that there is no significant mean difference in the cassava yield based on the farm location. Since there is a significant different between the fertilizers being compared and the interaction, we now apply the Tukey HSD pairwise comparison procedure on their corresponding mean yields. The results of the procedure are given in Table 1 in the appendix for the interaction of the two factors. It is obvious that only the interaction between Iron (Fe) and Location 2 and the interaction between Zinc (Zn) and Location 2 are significantly different at 5% level of significance.

Table 2. Analysis of variance table for the cassava yield data

Source	sum of squares	DF	Mean Square	F-ratio	Sig.
Fertilizer	78.738	2	39.368	9.076	.000
Farm Locations	11.003	4	2.751	0.634	.641
Interaction	83.537	8	10.442	2.407	.030
Error	195.190	45	4.338		
Total	368.466	59			

In Table 3, we have the Tukey HSD results for mean yields corresponding to fertilizers.

Table 3. Tukey HSD multiple comparison test: the fertilizer case

Test	Fertilizer (I)	Fertilizer (J)	Mean difference (I-J)	Standard Error	Sign.	95% Confidence Interval	
						Lower Bound	Upper Bound
Turkey HSD	Fe	Mn	-.6200	.65860	.617	-2.2162	.9762
		Zn	2.0600*	.65860	.009	.4638	3.6562
	Mn	Fe	.6200	.65860	.617	-.9762	2.2162
		Zn	2.6800*	.65860	.001	1.0838	4.2762
	Zn	Fe	-2.0600*	.65860	.009	-3.6562	-.4638
		Mn	-2.6800*	.65860	.001	-4.2762	-1.0838

The grouping in Table 4 is done using the results in Table 3.

Table 4. Grouping information using the Tukey Method and mean yield of fertilizer

Fertilizer	N	Mean	Grouping
Mn	20	12.57	A
Fe	20	11.95	A
Zn	20	9.89	B

The groupings of the mean fertilizer yield that do not share a letter are significantly different. This shows that the mean yields pertaining to Mn and Fe fertilizers are statistically different. However, they are statistically different from that of Zn.

4. CONCLUSION

In this paper, we have studied the effects of each of Mn, Fe and Zn, locations and their interactions on data on cassava yields using the two-way ANOVA with interaction. The results obtained in the course of analyzing the data indicate that the mean yields from the three fertilizers are significantly different. The effects of farm locations are not statistically significant. However, the results suggest that there is significant effect of the interaction of both factors on cassava yield. On the basis of the pairwise comparison of means, it is observed that only the between Iron (Fe) and Location 2 and the interaction between Zinc (Zn) and Location 2 are significantly different at 5% level of significance.

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