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Application of Three-Factor Factorial Experimental Design with 8 Replicates per Cell: A study of Maize Yield

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ABSTRACT

Factorial Experiments is one involving two or more factors in single experiments. Such designs are classified by the number of levels of each factors and the number of factors. Factorial experiments are efficient and provide extra information (the interactions between the factors) which cannot be obtained when using single factor design. This study examined the application of a three-factor factorial design in determine the significant difference in the mean yield of maize in Nigeria with respect to the effect of fertilizers, herbicides and water volumes. For the successful execution of this research work, primary data (yield of maize) were collected from farm land cultivated on half plot of land in the year 2016. The total ridges made were 216 which were segmented into (9), each containing 24 ridges. The 24 ridges were also segmented into 3, which makes it 8 replicates per factor level. This research work covers only three factors which are fertilizers at three levels {N:P:K(20:10:10), N:P:K(15:15:15), and UREA}, herbicides at three levels (Altraforce, Xtraforce and Metaforce) and water volumes at three levels (5litres, 7.5litres, and 10litres). The maize (Soar 1) was planted in June 2016, the herbicides (Altraforce, Xtraforce and Metaforce) were applied a day after planting, the water volumes (5Litres, 7.5Litres and 10Litres) were applied everyday according to how the ridges were segmented irrespective of rainfall.
The fertilizers {N:P:K(20:10:10), N:P:K(15:15:15), and UREA} were applied in August and the maize were harvested in September on the farm land and weighed per ridge in kilogram (kg). Data collected was analyzed electronically using SPSS version 21. The analysis techniques employed was a 3^3 replicated factorial design with 8 replicates per cell. The hypotheses tests were carried out at α (5%) significance level and the decision rule was to reject the null hypothesis (H_0) if the calculated Sig. value (p-value) is less than the α (5%). Results from the analyses revealed among others that there is significant difference in the fertilizers effect on the yield of maize with a Sig. value of 0.000 while there is no significant difference in the herbicides effect with a Sig. value of 0.505. Similarly, there is no significant difference in the water volumes effect on the yield of maize with a Sig. value of 0.866. In addition, there is significant interaction effect between "fertilizers and herbicides" (Sig. = 0.022) and between "herbicides and water volumes" (Sig. = 0.010) on the yield of maize.

Keywords: Application, Cell, Design, Experimental, Factor, Factorial, Maize, Replicates, Yield.

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INTRODUCTION

Sir Ronald Fisher, the statistician, eugenicist, evolutionary biologist, geneticist, and father of modern experimental design, observed that experiments are 'only experience carefully planned in advance, and designed to form a secure basis of new knowledge' (Fisher, 1935). Experiments are characterized by the: (1) manipulation of one or more independent variables; (2) use of controls such as randomly assigning participants or experimental units to one or more independent variables; and (3) careful observation or measurement of one or more dependent variables. The first and second characteristics—manipulation of an independent variable and the use of controls such as randomization—distinguish experiments from other research strategies.

In an experiment, we deliberately change one or more process variables (or factors) in order to observe the effect the changes have on one or more response variables. The (statistical) design of experiment (DOE) is an efficient procedure for planning experiments so that the data obtained can be analyzed to yield objective conclusions.

An experimental design is a plan for assigning experimental units to treatment levels and the statistical analysis associated with the plan (Kirk, 1995)

Design of experiments begins with determining the objectives of an experiment and selecting the process factors for the study. An experimental design is the laying out of a detailed experimental plan in advance of doing the experiment. Well chosen experimental design maximizes the amount of "information" that can be obtained for a given amount of experimental effort.

The experimenter has control over certain effect called treatment populations, or treatment combinations. The experimenter generally controls the choice of the experimental unit of whether are to be into groups called BLOCKS.

Design and analysis of experiment involve the use of statistical methods in planning and executing the research to ensure that necessary data are collected and processed to facilitate valid conclusions.

A factorial design as one of the areas of deign of experiment is often used by scientists wishing to understand the effect of two or more independent variables upon a single dependent variable.

Factorial experiments are experiments that investigate the effects of two or more factors or input parameters on the output response of a process. Factorial experimental design, or simply factorial design, is a systematic method for formulating the steps needed to successfully implement a factorial experiment. Estimating the effects of various factors on the output process with a minimal number of observations is crucial to being able to optimize the output of the process. In a factorial experiment, the effects of varying the levels of the various factors affecting the process output are investigated. Each complete trial or replication of the experiment takes into account all the possible combinations of the varying levels of these factors. Effective factorial design ensures that the least number of experiment runs are conducted to generate the maximum amount of information about how input variables affect the output of a process (Batra and Seema, 2012).

Traditionally research methods generally study the effect of one variable at a time, because it is statistically easier to manipulate. However, in many cases, two factors may be interdependent, and it is the impractical or false to attempt to analyze them in the traditional way.

Agricultural science researcher, with a need for field testing, often use factorial designs to test the effect of variables on crops. In such large scale studies, it is difficult and impracticable to isolate and test each variable individually.

Factorial experiment allows subtle manipulation of a large number of interdependent variables. Whilst the method has limitations, it is a useful method for streamlining research and letting powerful statistical methods highlight any correlations.

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Factorial design are extremely useful to field scientists as a preliminary study, allowing them to judge whether there is a link between variables, whilst reducing the possibility of experimental error and confounding variables.

The factorial design allows many levels of analysis as well as highlighting the relationship between variables. It also allows the effects of manipulating a single variable to be isolated and analyzed singly. A factorial design has to be planned meticulously, as an error in one of the levels or in the general operationalization will jeopardize a great amount of work. Other than these slight distractions, a factorial design is a mainstay of many scientific disciplines, delivering great result in the field.

It is to this effect that this research work aim to apply to the yield of maize, three-factor factorial design with "8" replicates per cell.

STATEMENT OF PROBLEM

Emphasis has been placed on maize yield research which involves the establishment of quantitative relationships between maize yields and multiple factors of production. Although numerous factors, both controlled and uncontrolled, affect maize production, the use of controlled variables such as plant nutrients from fertilizers has attracted the most attention.

It has been noted by many scientists that a particular maize may vary in its response to applied fertilizers depending on season and location effects. This presents a problem in extrapolating predicted yields from one experimental location to a larger geographical general area and, therefore, recommendations also. The causes of this uncertainty have, in general, been recognized, but not much attempts have been made to account for their effects on response of maize to applied fertilizers.

This uncertainty concerning the influence of uncontrolled variables accentuates the need to conduct yield research in a framework that will provide for the quantification of the effects of herbicides and water volume on the response of crops to applied fertilizers.

AIM AND OBJECTIVES OF THE STUDY

The aim of this research work is applying a three-factor factorial design in determine the significant effect of fertilizers, herbicides, and water volumes on the yield of maize.

The objectives are:

1. To determine the significant difference in the effect of fertilizers on the yield of maize.
2. To determine the significant difference in the effect of herbicides on the yield of maize.
3. To determine the significant difference in the effect of water volumes on the yield of maize.
4. To determine the significant interaction effect between fertilizers and herbicides on the yield of maize.
5. To determine the significant interaction effect between fertilizers and water volumes on the yield of maize.
6. To determine the significant interaction effect between herbicides and water volumes on the yield of maize.
7. To determine the significant interaction effect among fertilizers, herbicides and water volumes on the yield of maize.

SCOPE OF THE STUDY

There are many factors that can affect the yield of maize. This research work covers only three factors which are fertilizers {N:P:K(20:10:10), N:P:K(15:15:15), and UREA}, herbicides (Altraforce, Xtraforce and Metaforce) and water volumes (5litres, 7.5litres, and 10litres). The purpose of this research is to determine how these factors affect the yield of maize independently and collectively. The factorial design employed is a 3 x 3 x 3 replicated factorial design with 8 replicates per cell.

RESEARCH QUESTIONS

1. Is there significant difference in the fertilizers' effect on the yield of maize?
2. Is there significant difference in the herbicides' effect on the yield of maize?

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3. Is there significant difference in the water volumes' effect on the yield of maize?
4. Do the fertilizers and herbicides jointly have significant effect on the yield of maize or Is there significant interaction effect between fertilizers and herbicides?
5. Do the fertilizers and water volumes jointly have significant effect on the yield of maize or Is there significant interaction effect between fertilizers and water volumes?
6. Do the herbicides and water volumes jointly have significant effect on the yield of maize or Is there significant interaction effect between herbicides and water volumes?
7. Do the fertilizers, herbicides and water volumes jointly have significant effect on the yield of maize or Is there significant interaction effect among fertilizers, herbicides and water volumes?

RESEARCH HYPOTHESES

Based on the conceptual frame work and objectives of this research work, the following hypotheses direct the conduct and analysis of this research.

$\boldsymbol{H_0}$: Null Hypothesis
vs
$\boldsymbol{H_1}$: Alternative Hypothesis

Let $\boldsymbol{A_i}$ represents fertilizers' effect
$\boldsymbol{B_j}$ represents herbicides' effect
$\boldsymbol{C_k}$ represents water volumes' effect
$\boldsymbol{AB_{(ij)}}$ represents fertilizers and herbicides interaction's effect
$\boldsymbol{AC_{(ik)}}$ represents fertilizers and water volumes interaction's effect
$\boldsymbol{BC_{(jk)}}$ represents herbicides and water volumes interaction's effect
$\boldsymbol{ABC_{(ijk)}}$ represents fertilizers, herbicides and water volumes interaction's effect

TEST FOR MAIN EFFECTS

Fertilizers

$H_0: \boldsymbol{A_i = 0}$ (There is no significant difference in the fertilizers' effect on the yield of maize)

$H_1: \boldsymbol{A_i \neq 0}$ (There is significant difference in the fertilizers' effect on the yield of maize)

Herbicides

$H_0: \boldsymbol{B_j = 0}$ (There is no significant difference in the herbicides' effect on the yield of maize)

$H_1: \boldsymbol{B_j \neq 0}$ (There is significant difference in the herbicides' effect on the yield of maize)

Water Volumes

$H_0: \boldsymbol{C_k = 0}$ (There is no significant difference in the water volumes' effect on the yield of maize)

$H_1: \boldsymbol{C_k \neq 0}$ (There is significant difference in the water volumes' effect on the yield of maize)

TEST FOR INTERACTION EFFECTS

Fertilizers and Herbicides

$H_0: \boldsymbol{AB_{(ij)} = 0}$ (There is no significant interaction between fertilizers and herbicides on the yield of maize)

$H_1: \boldsymbol{AB_{(ij)} \neq 0}$ (There is significant interaction between fertilizers and

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herbicides on the yield of maize)

Fertilizers and Water Volumes

$H_0: \boldsymbol{AC_{(ik)}} = \mathbf{0}$ (There is no significant interaction between fertilizers and water volumes on the yield of maize)

$H_1: \boldsymbol{AC_{(ik)}} \neq \mathbf{0}$ (There is significant interaction between fertilizers and water volumes on the yield of maize)

Herbicides and Water Volumes

$H_0: \boldsymbol{BC_{(jk)}} = \mathbf{0}$ (There is no significant interaction between herbicides and water volumes on the yield of maize)

$H_1: \boldsymbol{BC_{(jk)}} \neq \mathbf{0}$ (There is significant interaction between herbicides and water volumes on the yield of maize)

Fertilizers, Herbicides and Water Volumes

$H_0: \boldsymbol{ABC_{(ijk)}} = \mathbf{0}$ (There is no significant interaction among fertilizers, herbicides and water volumes on the yield of maize)

$H_1: \boldsymbol{ABC_{(ijk)}} \neq \mathbf{0}$ (There is significant interaction among fertilizers, herbicides and water volumes on the yield of maize)

LITERATURE REVIEW

Maize (*Zea mays* L) is one of the major cereal crops grown in the humid tropics and Sub-Saharan Africa. It is a versatile crop and ranks third following wheat and rice in world production as reported by Food and Agriculture Organization (FAO, 2002). Maize crop is a key source of food and livelihood for millions of people in many countries of the world. It is produced extensively in Nigeria, where it is consumed roasted, baked, fried, pounded or fermented (Agbato, 2003). In advanced countries, it is an important source of many industrial products such as corn sugar, corn oil, corn flour, starch, syrup, brewer's grit and alcohol (Dutt, 2005). Corn oil is used for salad, soap-making and lubrication. Maize is a major component of livestock feed and it is palatable to poultry, cattle and pigs as it supplies them energy (Iken *et al.*, 2001). The stalk, leaves, grain and immature ears are cherished by different species of livestock (Dutt, 2005).

In spite of the increasing relevance and high demand for maize in Nigeria, yield across the country continues to decrease with an average of about 1 t/ha which is the lowest African yield recorded (Fayenisin, 1993). The steady decline in maize yield can be attributed to:

1. Rapid reduction in soil fertility caused by intensive use of land and reduction of fallow period as reported by Directorate of Information and Publications of Agriculture (DIPA, 2006).
2. Failure to identify and plant high yielding varieties most suited or adapted to each agro-ecological zone (Kim, 1997).
3. Use of inappropriate plant spacing which determines plant population and final yield (Zeidan *et al.*, 2006).

Tolera *et al.*, (1999) suggested that breeders should select maize varieties that combine high grain yield and desirable stover characteristics because of large differences that exist between cultivars. Odeleye and Odeleye (2001) reported that maize varieties differ in their growth characters, yield and its components, and therefore suggested that breeders must select most promising combiners in their breeding programmes.

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Factorial Experiment

Factorial Experiments is one involving two or more factors in single experiments. Such designs are classified by the number of levels of each factors and the number of factors. Factorial experiments are efficient and provide extra information (the interactions between the factors) which cannot be obtained when using single factor design.

If the investigator confines his attention to any single factor we may infer either that he is the unfortunate victim of a doctrinaire theory as to how experimentation should proceed, or that the time, material or equipment at his disposal is too limited to allow him to give attention to more than one aspect of his problem.

Indeed in a wide class of cases (by using factorial designs) an experimental investigation, at the same time as it is made more comprehensive, may also be made more efficient if by more efficient we mean that more knowledge and a higher degree of precision are obtainable by the same number of observations" (Fisher R. A. 1960).

Replication

It is the repetition of the experimental situation by replicating the experimental unit. In the replication principle, any treatment is repeated a number of times to obtain a valid and more reliable estimate than which is possible with one observation only. Replication provides an efficient way of increasing the precision of an experiment. The precision increases with the increase in the number of observations. Replication provides more observations when the same treatment is used, so it increases precision.

Suppose variance of x is σ^2, then variance of sample mean $\bar{x}$ based on n observations is $\frac{\sigma^2}{n}$. So as n increases $Var(\bar{x})$ decreases.

Three-factor factorial experiment with 'n' replicates per cell

From Table I below, the model for such an experiment is

$$Y_{ijkm} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + e_{ijkm} \qquad \_\_(1)$$

$i = 1, 2, \dots, a$ At a level of factor A
$j = 1, 2, \dots, b$ At b level of factor B
$k = 1, 2, \dots, c$ At c level of factor C
$m = 1, 2, \dots, n$ At n replicates per cell
μ is the base line mean.
A_i, B_j and C_k are the main factors' effects.
$(AB)_{ij}$, $(AC)_{ik}$ and $(BC)_{jk}$ are the two-factors' interaction effects.
$(ABC)_{IJK}$ is the three-factor interaction effect.
e_{ijkm} is the random error of the k^{th} observation from the (i, j, k)th treatment.
Where $e_{ijkm} \sim N(0, \sigma^2)$

Partitioning the sum of square for three-factor factorial design with 'n' replicates per cell

The model is defined as:

$$Y_{ijkm} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + e_{ijkm}$$

Let

$\mu = \bar{y}_{....}$
$A_i = \bar{y}_{i...} - \bar{y}_{....}$
$B_j = \bar{y}_{.j..} - \bar{y}_{....}$
$C_k = \bar{y}_{..k.} - \bar{y}_{....}$
$(AB)_{ij} = \bar{y}_{ij..} - \bar{y}_{i...} - \bar{y}_{.j..} + \bar{y}_{....}$
$(AC)_{ik} = \bar{y}_{i.k.} - \bar{y}_{i...} - \bar{y}_{..k.} + \bar{y}_{....}$
$(BC)_{jk} = \bar{y}_{.jk.} - \bar{y}_{.j..} - \bar{y}_{..k.} + \bar{y}_{....}$
$(ABC)_{ijk} = \bar{y}_{ijk.} - \bar{y}_{ij..} - \bar{y}_{i.k.} - \bar{y}_{.jk.} + \bar{y}_{i...} + \bar{y}_{.j..} + \bar{y}_{..k.} + \bar{y}_{....}$
$e_{ijkm} = y_{ijkm} - \bar{y}_{ijk.}$

Thus, substituting the notations into the model we have:

$$y_{ijkm} = \bar{y}_{....} + \left(\bar{y}_{i...} - \bar{y}_{....}\right) + \left(\bar{y}_{.j..} - \bar{y}_{....}\right) + \left(\bar{y}_{..k.} - \bar{y}_{....}\right) + \left(\bar{y}_{ij..} - \bar{y}_{i...} - \bar{y}_{.j..} + \bar{y}_{....}\right) + \left(\bar{y}_{i.k.} - \bar{y}_{i...} - \bar{y}_{..k.} + \bar{y}_{....}\right) + \left(\bar{y}_{.jk.} - \bar{y}_{.j..} - \bar{y}_{..k.} + \bar{y}_{....}\right) + \left(\bar{y}_{ijk.} - \bar{y}_{ij..} - \bar{y}_{i.k.} - \bar{y}_{.jk..} + \bar{y}_{i...} + \bar{y}_{.j..} + \bar{y}_{..k.} + \bar{y}_{....}\right) + \left(y_{ijkm} - \bar{y}_{ijk.}\right) \qquad \_\_(2)$$

$$\Rightarrow \left(y_{ijkm} - \bar{y}_{....}\right) = \left(\bar{y}_{i...} - \bar{y}_{....}\right) + \left(\bar{y}_{.j..} - \bar{y}_{....}\right) + \left(\bar{y}_{..k.} + \bar{y}_{....}\right) + \left(\bar{y}_{ij..} - \bar{y}_{i...} - \bar{y}_{.j..} + \bar{y}_{....}\right) + \left(\bar{y}_{i.k.} - \bar{y}_{i...} - \bar{y}_{..k.} + \bar{y}_{....}\right) + \left(\bar{y}_{.jk.} - \bar{y}_{.j..} - \bar{y}_{..k.} +\right.$$

$\bar{y}_{....}) + (\bar{y}_{ijk.} - \bar{y}_{ij..} - \bar{y}_{i.k.} - \bar{y}_{.jk..} + \bar{y}_{i...} + \bar{y}_{.j..} + \bar{y}_{..k.} + \bar{y}_{....}) + (y_{ijkm} - \bar{y}_{ijk.})$ __(3)

Let

$(y_{ijkm} - \bar{y}_{....}) = p$

$(\bar{y}_{i...} - \bar{y}_{....}) = q$

$(\bar{y}_{.j..} - \bar{y}_{....}) = r$

$(\bar{y}_{..k.} + \bar{y}_{....}) = s$

$(\bar{y}_{ij..} - \bar{y}_{i...} - \bar{y}_{.j..} + \bar{y}_{....}) = t$

$(\bar{y}_{i.k.} - \bar{y}_{i...} - \bar{y}_{..k.} + \bar{y}_{....}) = u$

$(\bar{y}_{.jk.} - \bar{y}_{.j..} - \bar{y}_{..k.} + \bar{y}_{....}) = v$

$(\bar{y}_{ijk.} - \bar{y}_{ij..} - \bar{y}_{i.k.} - \bar{y}_{.jk..} + \bar{y}_{i...} + \bar{y}_{.j..} + \bar{y}_{..k.} + \bar{y}_{....}) = w$

$(y_{ijkm} - \bar{y}_{ijk.}) = x$

So that

$p = q + r + s + t + u + v + w + x$ __(4)

Squaring both sides, we have:

$p^2 = (q + r + s + t + u + v + w + x)^2$ __(5)

That is

$p^2 = q^2 + 2qr + 2qs + 2qt + 2qu + 2qv + 2qw + 2qx + r^2 + 2rs + 2rt + 2rt + 2rv + 2rw + 2rx + s^2 + 2st + 2su + 2sv + 2sw + 2sx + t^2 + 2tu + 2tv + 2tw + 2tx + u^2 + 2uv + 2uw + 2ux + v^2 + 2vw + 2vx + w2 + 2wx + x^2$ __(6)

Summing equation __(6) across i^{th} level of factor A, j^{th} level of factor B, k^{th} level of factor C and n replicates per cell respectively, we have it reduced to:

$$\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c}\sum_{m=1}^{n} p^2 = bcn\sum_{i=1}^{a} q^2 + acn\sum_{j=1}^{b} r^2 + abn\sum_{k=1}^{c} s^2 + nc\sum_{i=1}^{a}\sum_{j=1}^{b} t^2 + nb\sum_{i=1}^{a}\sum_{k=1}^{c} u^2 + na\sum_{j=1}^{b}\sum_{k=1}^{c} v^2 + n\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c} w^2 + \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c}\sum_{m=1}^{n} x^2$$ __(7)

Where,

$$SST = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c}\sum_{m=1}^{n} (y_{ijkm} - \bar{y}_{....})^2$$ __(8)

$$SS_A = nbc\sum_{i=1}^{a} (\bar{y}_{i...} - \bar{y}_{....})^2$$ __(9)

$$SS_B = nac\sum_{j=1}^{b} (\bar{y}_{.j..} - \bar{y}_{....})^2$$ __(10)

$$SS_C = nab\sum_{k=1}^{c} (\bar{y}_{..k.} - \bar{y}_{....})^2$$ __(11)

$$SS_{AB} = nc\sum_{i=1}^{a}\sum_{j=1}^{b} (\bar{y}_{ij..} - \bar{y}_{i...} - \bar{y}_{.j..} + \bar{y}_{....})^2$$ __(12)

$$SS_{AC} = nb\sum_{i=1}^{a}\sum_{k=1}^{c} (\bar{y}_{i.k.} - \bar{y}_{i...} - \bar{y}_{..k.} + \bar{y}_{....})^2$$ __(13)

$$SS_{BC} = na\sum_{j=1}^{b}\sum_{k=1}^{c} (\bar{y}_{.jk.} - \bar{y}_{.j..} - \bar{y}_{..k.} + \bar{y}_{....})^2$$ __(14)

$$SS_{ABC} = n\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c} (\bar{y}_{ijk.} - \bar{y}_{ij..} - \bar{y}_{i.k.} - \bar{y}_{.jk..} + \bar{y}_{i...} + \bar{y}_{.j..} + \bar{y}_{..k.} + \bar{y}_{....})^2$$ __(15)

$$SS_{ERROR} = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c}\sum_{m=1}^{n} (y_{ijkm} - \bar{y}_{ijk.})^2$$

__(16)

That is,

$$SS_T = SS_A + SS_B + SS_C + SS_{AB} + SS_{AC} + SS_{BC} + SS_{ABC} + SS_E \qquad \_\_(17)$$

METHODOLOGY

Research Design

In this research work, primary data (yield of maize) were collected from farm cultivated on half plot of land in the year 2016. The half plot of land was first cleared before the ridges were made, the total ridges made were 216 which were segmented into (9), each containing 24 ridges. The 24 ridges were also segmented into 3, which makes it 8 replicates per factor level. The maize (Soar 1) was planted in June 2016, the herbicides (Altraforce, Xtraforce and Metaforce) were applied a day after planting, the water volumes (5Litres, 7.5Litres and 10Litres) were also applied everyday according to how the ridges were segmented irrespective of rainfall.

The fertilizers {N:P:K(20:10:10), N:P:K(15:15:15), and UREA} were applied in August and the maize were harvested in September on the farm land and weighed per ridge in kilogram (kg).

In this research work, there is one dependent variable (Maize yield) and three independent variables (Fertilizers, Herbicide and Water volume) each at three levels.

The experimental design employed was a 3×3×3 factorial experimental design with eight (8) replicates per cell.

The maize yield data collected was presented in Table III below.

Data collected were analyzed electronically using Statistical Package for Social Science (SPSS) version 21.

Method of data collection and analysis

Data for this research was collected primarily via experimental/observation method. Collected data was analyzed using a factorial design analysis which involves partitioning the design model into appropriate Sum of Squares (SS) with respective degree of freedoms as sampled in Table II below.

$$SS_{TOTAL} = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c}\sum_{m=1}^{n} y_{ijkm}^2 - \frac{(y_{....})^2}{nabc}$$

$$SS_{FERTILIZER} = \sum_{i=1}^{a} \frac{\bar{y}_{i...}^2}{nbc} - \frac{(y_{....})^2}{nabc}$$

With (3 – 1) = 2 degree of freedom.

$$SS_{HERBICIDE} = \sum_{j=1}^{b} \frac{\bar{y}_{.j..}^2}{nac} - \frac{(y_{....})^2}{nabc}$$

With (3 – 1) = 2 degree of freedom.

$$SS_{WATER\,VOLUME} = \sum_{k=1}^{c} \frac{\bar{y}_{..k.}^2}{nab} - \frac{(y_{....})^2}{nabc}$$

With (3 – 1) = 2 degree of freedom.

$$SS_{FERTILIZER\,AND\,HERBICIDE} = \sum_{i=1}^{a}\sum_{j=1}^{b} \frac{\bar{y}_{ij..}^2}{nc} - \frac{(y_{....})^2}{nabc} - SS_{FERTILIZER} - SS_{HERBICIDE}$$

With 4 degree of freedom.

$$SS_{FERTILIZER\,AND\,WATER} = \sum_{i=1}^{a}\sum_{k=1}^{c} \frac{\bar{y}_{i.k.}^2}{nb} - \frac{(y_{....})^2}{nabc} - SS_{FERTILIZER} - SS_{WATER\,VOLUME}$$

With 4 degree of freedom.

$$SS_{HERBICIDE\,AND\,WATER} = \sum_{j=1}^{b}\sum_{k=1}^{c} \frac{\bar{y}_{.jk.}^2}{na} - \frac{(y_{....})^2}{nabc} - SS_{HERBICIDE} - SS_{WATER\,VOLUME}$$

With 4 degree of freedom.

$$SS_{FERTILIZER,\ HERBCIDE\ AND\ WATER} = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c}\frac{\bar{y}_{ijk.}^2}{n} - \frac{(y_{....})^2}{nabc} - SS_{FERTILIZER} - SS_{HERBICIDE} - SS_{WATER\ VOLUME} - SS_{FERTILIZER\ AND\ HERBICIDE} - SS_{FERTILIZER\ AND\ WATER} - SS_{HERBICIDE\ AND\ WATER}$$

With 8 degree of freedom.

$$SS_{ERROR} = SS_{TOTAL} - SS_{FERTILIZER} - SS_{HERBICIDE} - SS_{WATER\ VOLUME} - SS_{FERTILIZER\ AND\ HERBICIDE} - SS_{FERTILIZER\ AND\ WATER\ VOLUME} - SS_{HERBICIDE\ AND\ WATER\ VOLUME} - SS_{FERTILIZER,\ HERBICIDE\ AND\ WATER\ VOLUME}$$

With 189 degree of freedom.

The F-ratio is calculated by dividing each of the mean squares by the mean squares error to derive the corresponding F-ratio.

The hypotheses tests were carried out at α (5%) significance level and the decision rule was to reject the null hypothesis (H_0) if the calculated *Sig.* value (*p*-value) is less than the α (5%).

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Table I: *Typical table of a three-factor factorial experimental design with n replicates per cell*

		A												
		1				2				…	*a*			
		C				**C**					**C**			
		1	2	…	*c*	1	2	…	*c*	…	1	2	…	*c*
		y_{1111}	y_{1121}	…	y_{11c1}	y_{2111}	y_{2121}	…	y_{21c1}	…	y_{a111}	y_{a121}	…	y_{a1c1}
		y_{1112}	y_{1122}	…	y_{11c2}	y_{2112}	y_{2122}	…	y_{21c2}	…	y_{a112}	y_{a122}	…	y_{a1c2}
		y_{1113}	y_{1123}	…	y_{11c3}	y_{2113}	y_{2123}	…	y_{21c3}	…	y_{a113}	y_{a123}	…	y_{a1c3}
	1	.	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.	.
		y_{111n}	y_{112n}	…	y_{11cn}	y_{211n}	y_{212n}	…	y_{21cn}	…	y_{a111n}	y_{a12n}	…	y_{a1cn}
		y_{1211}	y_{1221}	…	y_{12c1}	y_{2211}	y_{2221}	…	y_{22c1}	…	y_{a211}	y_{a221}	…	y_{a2c1}
		y_{1212}	y_{1222}	…	y_{12c2}	y_{2212}	y_{2222}	…	y_{22c2}	…	y_{a212}	y_{a222}	…	y_{a2c2}
		y_{1213}	y_{1223}	…	y_{12c3}	y_{2213}	y_{2223}	…	y_{2233}	…	y_{3213}	y_{a223}	…	y_{a2c3}
	2	.	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.	.
B		y_{121n}	y_{122n}	…	y_{12cn}	y_{221n}	y_{222n}	…	y_{22cn}	…	y_{a31n}	y_{a22n}	…	y_{a2cn}
	.		.				.			.		.		
	.		.				.			.		.		
	.		.				.			.		.		

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		y_{1b11}	y_{1b21}	$\cdots$	y_{1bc1}	y_{2b11}	y_{2b21}	$\cdots$	y_{2bc1}	$\cdots$	y_{ab11}	y_{ab21}	$\cdots$	y_{abc1}
		y_{1b12}	y_{1b22}	$\cdots$	y_{1bc2}	y_{2b12}	y_{2b22}	$\cdots$	y_{2bc2}	$\cdots$	y_{ab12}	y_{ab22}	$\cdots$	y_{abc2}
		y_{1b13}	y_{1b23}	$\cdots$	y_{1bc3}	y_{2b13}	y_{2b23}	$\cdots$	y_{2bc3}	$\cdots$	y_{a313}	y_{ab23}	$\cdots$	y_{abc3}
	b	.	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.	.	.	.
		y_{1b1n}	y_{1b2n}	$\cdots$	y_{1bcn}	y_{2b1n}	y_{2b2n}	$\cdots$	y_{2bcn}	$\cdots$	y_{ab1n}	y_{ab2n}	$\cdots$	y_{abcn}

Table II: *ANOVA table for three-factor factorial design*

Source of Variation	*Sum of Squares*	*Degree of Freedom*	*Mean Square*	*F-ratio*
A	SS_A	$(a-1)$	$\frac{SS_A}{(a-1)}$	$\frac{MS_A}{MS_E}$
B	SS_B	$(b-1)$	$\frac{SS_B}{(b-1)}$	$\frac{MS_A}{MS_E}$
C	SS_C	$(c-1)$	$\frac{SS_C}{(c-1)}$	$\frac{MS_C}{MS_E}$
AB	SS_{AB}	$(a-1)(b-1)$	$\frac{SS_{AB}}{(a-1)(b-1)}$	$\frac{MS_{AB}}{MS_E}$
AC	SS_{AC}	$(a-1)(c-1)$	$\frac{SS_{AC}}{(a-1)(c-1)}$	$\frac{MS_{AC}}{MS_E}$

BC	SS_{BC}	$(b-1)(c-1)$	$\frac{SS_{BC}}{(b-1)(c-1)}$	$\frac{MS_{BC}}{MS_E}$
ABC	SS_{ABC}	$(a-1)(b-1)(c-1)$	$\frac{SS_{ABC}}{(a-1)(b-1)(c-1)}$	$\frac{MS_{ABC}}{MS_E}$
Error	SS_{ERROR}	$abc\,(n-1)$	$\frac{SS_{ERROR}}{abc\,(n-1)}$	
Total	SS_{TOTAL}	$N-1$		

Table III: *3^3 Factorial design of maize yield (kg) with 8 replicates per cell*

HERBICIDES		FERTILIZER								
		NPK 201010			NPK 151515			UREA		
		WATER VOLUME			**WATER VOLUME**			**WATER VOLUME**		
		5 liters	7.5 liters	10 liters	5 liters	7.5 liters	10 liters	5 liters	7.5 liters	10 liters

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	ALTRAFORCE	0.10	0.10	0.16	0.17	0.19	0.19	0.04	0.02	0.15
		0.03	0.10	0.10	0.13	0.14	0.30	0.05	0.22	0.20
		0.24	0.33	0.09	0.10	0.90	0.24	0.15	0.15	0.11
		0.09	0.05	0.12	0.12	0.13	0.15	0.13	0.10	0.15
		0.07	0.30	0.11	0.03	0.23	0.37	0.04	0.15	0.15
		0.15	0.05	0.11	0.24	0.15	0.50	0.04	0.15	0.15
		0.18	0.10	0.11	0.10	0.15	0.20	0.12	0.15	0.15
		0.12	0.14	0.11	0.17	0.15	0.20	0.12	0.15	0.15
	XTRAFORCE	0.17	0.25	0.14	0.35	0.16	0.11	0.13	0.15	0.07
		0.24	0.19	0.08	0.37	0.13	0.19	0.11	0.11	0.16
		0.15	0.11	0.29	0.35	0.34	0.24	0.10	0.16	0.05
		0.16	0.26	0.19	0.26	0.17	0.09	0.13	0.10	0.12
		0.18	0.20	0.09	0.05	0.10	0.26	0.15	0.06	0.03
		0.04	0.20	0.10	0.12	0.70	0.47	0.05	0.13	0.04
		0.19	0.20	0.01	0.30	0.05	0.24	0.12	0.13	0.08
		0.19	0.20	0.11	0.12	0.16	0.08	0.91	0.13	0.08
	METAFORCE	0.04	0.04	0.14	0.06	0.11	0.19	0.24	0.20	0.04
		0.34	0.06	0.14	0.09	0.11	0.17	0.10	0.12	0.08
		0.44	0.10	0.16	0.16	0.07	0.29	0.15	0.14	0.15
		0.24	0.12	0.14	0.06	0.02	0.27	0.06	0.15	0.16
		0.13	0.12	0.15	0.25	0.05	0.03	0.13	0.10	0.10
		0.25	0.12	0.19	0.24	0.10	0.13	0.08	0.11	0.14
		0.16	0.12	0.09	0.17	0.16	0.17	0.15	0.16	0.15
		0.27	0.12	0.11	0.17	0.29	0.18	0.15	0.20	0.14

Source: Field Experiment (2016).

DATA PRESENTATION

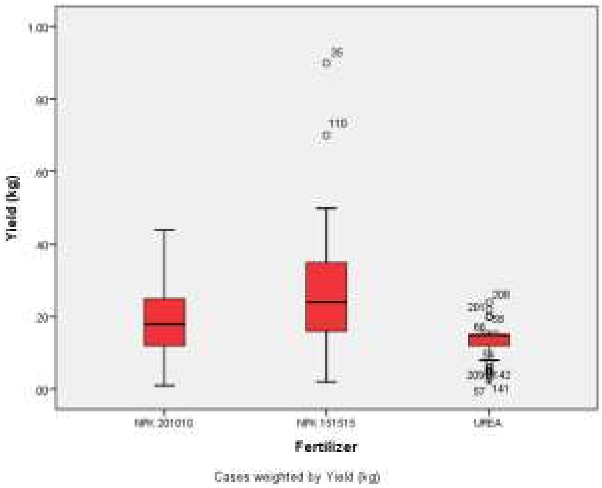

Figure I: *Boxplot of Fertilizers*

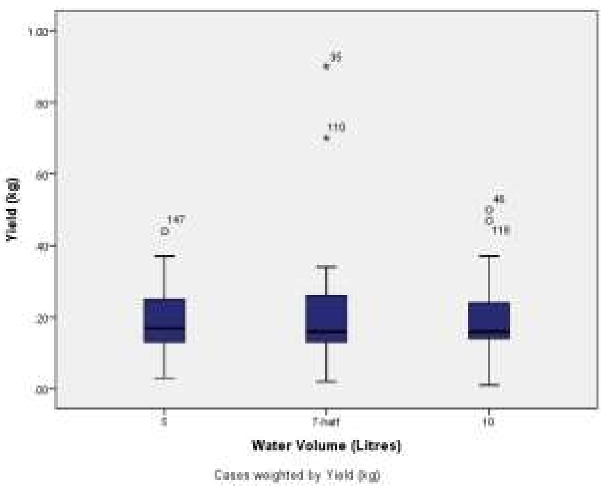

Figure II: *Boxplot of Water volumes*

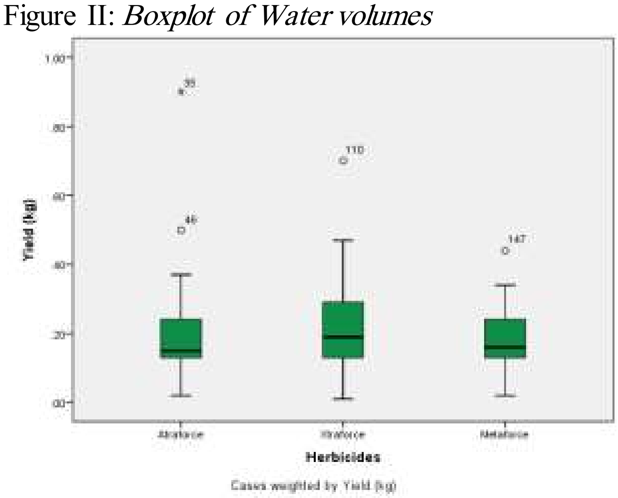

Figure III: *Boxplot of Herbicides*

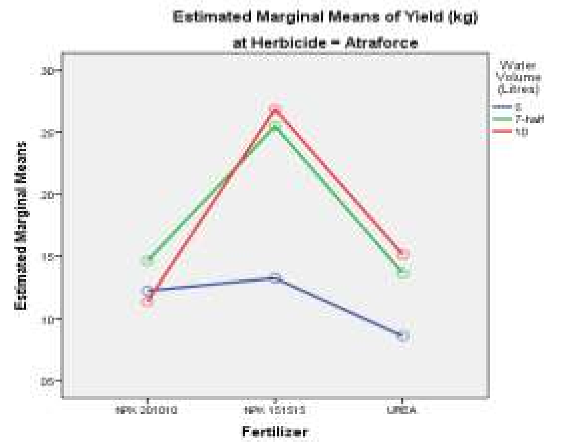

Figure IV: *Mean plot of Fertilizers, Water volumes and Herbicides, at Herbicide = Atraforce*

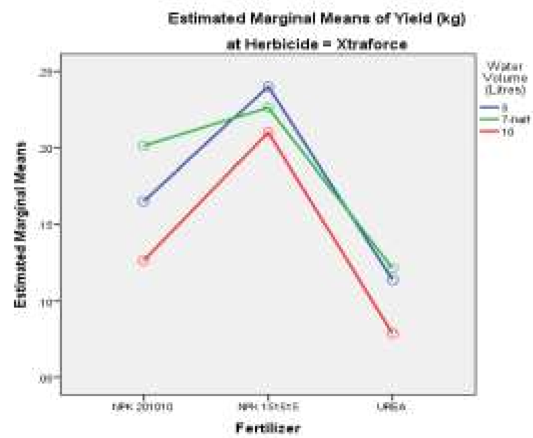

Figure V: *Mean plot of Fertilizers, Water volumes and Herbicides, at Herbicide = Xraforce*

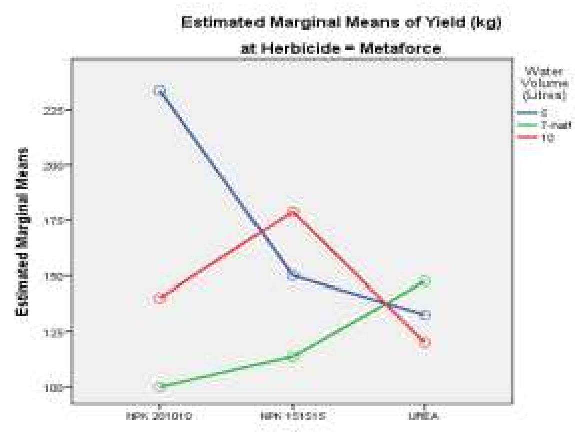

Figure VI: *Mean plot of Fertilizers, Water volumes and Herbicides, at Herbicide = Metaforce*

RESULT

Table IV: Between-Subjects Factors

		Value Label	N
Fertilizer	1	NPK 201010	72
	2	NPK 151515	72
	3	UREA	72
Water Volume (Litres)	1	5	72
	2	7-half	72
	3	10	72
Herbicide	1	Atraforce	72
	2	Xtraforce	72
	3	Metaforce	72

Table V: Tests of Between-Subjects Effects (ANOVA)

Dependent Variable: Yield (kg)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	5.830[a]	27	.216	23.930	.000
Fertilizer	.214	2	.107	11.864	.000
Water	.003	2	.001	.145	.866
Herbicide	.012	2	.006	.686	.505
Fertilizer * Water Volume	.056	4	.014	1.551	.189
Fertilizer * Herbicide	.106	4	.027	2.938	.022
Water * Herbicide	.123	4	.031	3.405	.010
Fertilizer * Water Volume * Herbicide	.061	8	.008	.850	.560
Error	1.705	189	.009		
Total	7.536	216			

a. R Squared = .774 (Adjusted R Squared = .741)

Table VI: Estimated marginal mean of Fertilizers

Dependent Variable: Yield (kg)

Fertilizer	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
N:P:K(20:10:10)	.150	.011	.128	.172
N:P:K(15:15:15)	.197	.011	.175	.219
UREA	.121	.011	.099	.143

Table VII: Pairwise comparisons of Fertilizers

Dependent Variable: Yield (kg)

(I) Fertilizer	(J) Fertilizer	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
N:P:K (20:10:10)	N:P:K (15:15:15)	-.047*	.016	.003	-.079	-.016
	UREA	.029	.016	.068	-.002	.060
N:P:K (15:15:15)	N:P:K (20:10:10)	.047*	.016	.003	.016	.079
	UREA	.076*	.016	.000	.045	.108
UREA	N:P:K (20:10:10)	-.029	.016	.068	-.060	.002
	N:P:K (15:15:15)	-.076*	.016	.000	-.108	-.045

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table VIII: Univariate tests of Fertilizers

Dependent Variable: Yield (kg)

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.214	2	.107	11.864	.000
Error	1.705	189	.009		

The F tests the effect of Fertilizer. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Table IX: Estimated marginal mean of Water volumes

Dependent Variable: Yield (kg)

Water Volume (Litres)	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
5	.153	.011	.131	.175
7.5	.161	.011	.139	.183
10	.154	.011	.132	.176

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Table X: Pairwise comparisons of Water volumes
Dependent Variable: Yield (kg)

(I) Water Volume (Litres)	(J) Water Volume (Litres)	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
5	7.5	-.008	.016	.618	-.039	.023
	10	-.001	.016	.937	-.032	.030
7.5	5	.008	.016	.618	-.023	.039
	10	.007	.016	.674	-.025	.038
10	5	.001	.016	.937	-.030	.032
	7.5	-.007	.016	.674	-.038	.025

Based on estimated marginal means
a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table XI: Univariate tests of Water volumes

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.003	2	.001	.145	.866
Error	1.705	189	.009		

The F tests the effect of Water Volume (Litres). This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Table XII: Estimated marginal mean of Herbicides
Dependent Variable: Yield (kg)

Herbicide	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Atraforce	.157	.011	.135	.179
Xtraforce	.165	.011	.143	.187
Metaforce	.146	.011	.124	.168

Table XIII: Pairwise comparisons of Herbicides
Dependent Variable: Yield (kg)

(I) Herbicide	(J) Herbicide	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
Atraforce	Xtraforce	-.008	.016	.624	-.039	.023
	Metaforce	.011	.016	.500	-.021	.042
Xtraforce	Atraforce	.008	.016	.624	-.023	.039
	Metaforce	.018	.016	.245	-.013	.050
Metaforce	Atraforce	-.011	.016	.500	-.042	.021
	Xtraforce	-.018	.016	.245	-.050	.013

Based on estimated marginal means
a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table XIV: Univariate tests of Herbicide
Dependent Variable: Yield (kg)

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	.012	2	.006	.686	.505
Error	1.705	189	.009		

The F tests the effect of Herbicide. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Table XV: Pairwise comparisons of Fertilizers and Water volumes
Dependent Variable: Yield (kg)

Fertilizer	Water Volume (Litres)	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
N:P:K(20:10:10)	5	.174	.019	.136	.212
	7.5	.149	.019	.111	.187
	10	.127	.019	.088	.165
N:P:K(15:15:15)	5	.174	.019	.136	.212
	7.5	.198	.019	.160	.237
	10	.219	.019	.181	.257
UREA	5	.111	.019	.073	.149
	7.5	.135	.019	.097	.173
	10	.117	.019	.078	.155

Table XVI: Pairwise comparisons of Fertilizers and Herbicides
Dependent Variable: Yield (kg)

Fertilizer	Herbicide	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
N:P:K(20:10:10)	Atraforce	.128	.019	.089	.166
	Xtraforce	.164	.019	.126	.202
	Metaforce	.158	.019	.120	.196
N:P:K(15:15:15)	Atraforce	.219	.019	.181	.257
	Xtraforce	.225	.019	.187	.264
	Metaforce	.148	.019	.109	.186
UREA	Atraforce	.125	.019	.086	.163
	Xtraforce	.105	.019	.066	.143
	Metaforce	.133	.019	.095	.172

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Table XVII: Pairwise comparisons of Water volumes and Herbicides
Dependent Variable: Yield (kg)

Water Volume (Litres)	Herbicide	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
5	Atraforce	.114	.019	.076	.152
	Xtraforce	.173	.019	.135	.211
	Metaforce	.172	.019	.134	.210
7.5	Atraforce	.179	.019	.141	.217
	Xtraforce	.183	.019	.145	.221
	Metaforce	.120	.019	.082	.159
10	Atraforce	.178	.019	.140	.216
	Xtraforce	.138	.019	.100	.177
	Metaforce	.146	.019	.108	.184

Table XVIII: Pairwise comparisons of Fertilizers, Water volumes and Herbicides
Dependent Variable: Yield (kg)

Fertilizer	Water Volume (Litres)	Herbicide	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
N:P:K (20:10:10)	5	Atra force	.123	.034	.056	.189
		Xtra force	.165	.034	.099	.231
		Meta force	.234	.034	.168	.300
	7.5	Atra force	.146	.034	.080	.212
		Xtra force	.201	.034	.135	.267
		Meta force	.100	.034	.034	.166
	10	Atra force	.114	.034	.048	.180
		Xtra force	.126	.034	.060	.192
		Meta force	.140	.034	.074	.206
N:P:K (15:15:15)	5	Atra force	.133	.034	.066	.199
		Xtra force	.240	.034	.174	.306
		Meta force	.150	.034	.084	.216
	7.5	Atra force	.255	.034	.189	.321
		Xtra force	.226	.034	.160	.292
		Meta force	.114	.034	.048	.180
	10	Atra force	.269	.034	.203	.335
		Xtra force	.210	.034	.144	.276
		Meta force	.179	.034	.113	.245
UREA	5	Atra force	.086	.034	.020	.152
		Xtra force	.114	.034	.048	.180
		Meta force	.133	.034	.066	.199
	7.5	Atra force	.136	.034	.070	.202
		Xtra force	.121	.034	.055	.187
		Meta force	.148	.034	.081	.214
	10	Atra force	.151	.034	.085	.217
		Xtra force	.079	.034	.013	.145
		Meta force	.120	.034	.054	.186

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Table XIX: *Summary of results*

Source		*Sig.*	*Remark*
Fertilizer		.000	Significant
Water		.866	Insignificant
Herbicide		.505	Insignificant
Fertilizer * Water Volume		.189	Insignificant
Fertilizer * Herbicide		.022	Significant
Water * Herbicide		.010	Significant
Fertilizer * Water Volume * Herbicide		.560	Insignificant
FERTILIZER			
N:P:K (20:10:10)	N:P:K (15:15:15)	.003	Significant
	UREA	.068	Insignificant
N:P:K (15:15:15)	N:P:K (20:10:10)	.003	Significant
	UREA	.000	Significant
UREA	N:P:K (20:10:10)	.068	Insignificant
	N:P:K (15:15:15)	.000	Significant
WATER VOLUME			
5	7.5	.618	Insignificant
	10	.937	Insignificant
7.5	5	.618	Insignificant
	10	.674	Insignificant
10	5	.937	Insignificant
	7.5	.674	Insignificant
HERBICIDE			
Atraforce	Xtraforce	.624	Insignificant
	Metaforce	.500	Insignificant
Xtraforce	Atraforce	.624	Insignificant
	Metaforce	.245	Insignificant
Metaforce	Atraforce	.500	Insignificant
	Xtraforce	.245	Insignificant

DISCUSSION OF RESULTS

From the ANOVA table (Table V), the *Sig.* value of 0.000 for Fertilizers implies that the null hypothesis of no significant difference in the fertilizers effect on the yield of maize is rejected. The *Sig.* value of 0.866 for Water volumes implies that the null hypothesis of no significant difference in the water volumes effect on the yield of maize is not rejected. The *Sig.* value of 0.505 for Herbicides implies that the null hypothesis of no significant difference in the herbicides effect on the yield of maize is not rejected. The *Sig.* value of 0.189 for Fertilizers and Water volumes interaction implies that the null hypothesis of no significant interaction between fertilizers and water volumes on the yield of maize is not rejected. The *Sig.* value of 0.022 for Fertilizers and Herbicides interaction implies that the null hypothesis of no significant interaction between fertilizers and herbicides on the yield of maize is rejected. The *Sig.* value of 0.001 for Water volumes and Herbicides interaction implies that the null hypothesis of no significant interaction between fertilizers and herbicides on the yield of maize is rejected. The *Sig.* value of 0.560 for Fertilizers, Water volumes and Herbicides interaction implies that the null hypothesis of no significant interaction between fertilizers, water volumes and herbicides on the yield of maize is not rejected.

From Table VI, the mean yield of maize by N:P:K(20:10:10), N:P:K(15:15:15) and UREA is 0.150kg, 0.197kg and 0.121kg respectively. From Table VII, the mean maize yield difference between N:P:K(20:10:10) and N:P:K(15:15:15), N:P:K(20:10:10) and UREA, N:P:K(15:15:15) and UREA is 0.047kg, 0.029 and 0.076 respectively. Of these mean yield difference between the fertilizers, only the differences between N:P:K(20:10:10) and N:P:K(15:15:15), N:P:K(15:15:15) and UREA are significant with a Sig. value of 0.003 and 0.000 respectively.

From Table IX, mean yield of maize by 5litres, 7.5litres and 10litres of water is 0.153kg, 0.161kg and 0.154kg respectively. From Table X, the mean maize yield difference between 5litres and 7.5litres, 5litres and 10litres, 7.5litres and 10litres is 0.008kg, 0.001kg and 0.007kg respectively. However none of the mean yield differences is significant.

From Table XII, the mean yield of maize by Atraforce, Xtraforce and Metaforce is 0.157kg, 0.165kg and 0.146kg respectively. From Table XIII, the mean maize yield difference between Atraforce and Xtraforce, Atraforce and Metaforce, Xtraforce and Metaforce is 0.008kg, 0.011kg, and 0.018kg respectively. However none of the mean yield difference is significant.

CONCLUSIONS

On the basis of the scope, methodology and analysis of the data, it can be concluded that at 5% significant level:

1. There is significant difference in the fertilizers effect on the yield of maize.
2. There is no significant difference in the herbicides effect on the yield of maize.
3. There is no significant difference in the water volumes effect on the yield of maize.
4. There is significant interaction effect between fertilizers and herbicides on the yield of maize.
5. There is no significant interaction effect between fertilizers and water volumes on the yield of maize.
6. There is significant interaction effect between herbicides and water volumes on the yield of maize.
7. There is no significant interaction effect between fertilizers, herbicides and water volumes on the yield of maize.

RECOMMENDATIONS

In the light of the findings of this study, the following recommendations are made for adequate maize yield in Nigeria.

1. The significant difference in the fertilizers effect on the yield of maize implies that the three fertilizers do not perform equally on the yield. A look at the fertilizers' marginal means therefore suggest that N:P:K(15:15:15) performs better with a mean of 0.197. Hence, it is

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recommended for maize planting for optimal yield.

2. Any of the three herbicides is recommended for maize weed control since they have equal effect on the yield.
3. Any of the three water levels is suitable for maize planting since they have equal effect on the yield.
4. The significant difference in the interaction effect of fertilizers and herbicides implies that they do not have equal effect on the yield. A look at the marginal means therefore suggests that combination of N:P:K(15:15:15) fertilizer and Xtraforce herbicide interact better with a mean of 0.225. Hence, it is recommended for maize planting for optimal yield.
5. Any of the fertilizers and water volumes combination is recommended for maize planting since they have equal effect on the yield.
6. The significant difference in the interaction effect of herbicides and water volume implies that they do not have equal effect on the yield. A look at the marginal means therefore suggests that combination of 7.5litres of water volume and Xtraforce herbicide interact better with a mean of 0.183. Hence, it is recommended for maize planting for optimal yield.
7. Any of the fertilizers, herbicides and water volumes combination is recommended for maize planting since they have equal effect on the yield.

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APPENDIX

Images from the Field Experiment (Maize Planting)

THE MAIZE SEED (SOAR 1)

HERBICIDES

WATER VOLUMES

RIDGES MAKING

PLANTING PROCESS

APPLICATION OF HERBICIDES

APPLICATION OF FERTILIZERS

MAIZE GERMINATION

HARVESTING AND WEIGHING