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A MIXED-LEVEL FACTORIAL EXPERIMENT TO ELUCIDATE THE IMPACT OF INORGANIC FERTILIZERS ON CROP YIELD

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ABSTRACT: *Lack of nutrients in the soil affects soil fertility which can hinder the growth and yield of any crop. Therefore, soil amendment is important to improve soil nutrient either by organic or inorganic technique. In this paper, we considered different inorganic fertilizers to determine the main optimal effect and their interaction on the yield of crop by adoption of mixed-level factorial experiment. Three inorganic fertilizers namely Nitrogen (N), Phosphorous (P) and Potassium (K) were considered each at different levels using tomato crop for investigation. We set up a multiple linear model to match with the design. We estimated the model parameters with the error component and sums of squares. A 2×3×4 design structure for factorial combinations—of factor N at two levels, factor P at three levels, and factor K at four levels using a randomized complete block design with three replications—was developed. Normality of the data was tested and factors visualization for both main and interaction effects were illustrated by the use of graphs. The result revealed that Nitrogen (N) and Potassium (K) concentration are significant while Phosphorous (P) concentration is not, the effect of two-factor interactions for NP and PK are not significant and NK is significant, which signified that the yields do not depend on the levels irrespective of the factor. Based on the results, we concluded that phosphorus is the best inorganic fertilizer compared with Nitrogen and Potassium in terms of soil nutrient for the yield of crops.*

KEYWORDS: Soil, Inorganic fertilizer, Crop, Tomatoes, Yield, Factorial experiment.

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INTRODUCTION

Soil quality is affected by compaction, loss of soil structure, nutrient degradation and soil salinity which can hinder the yield of crops. Declining fertility is the soil constraint and problem which militates against high crop yields that enable investigation. The conservation and management measure to improve high crop yield is by fertilization. Fertilization is a direct strategy to boost productivity and most productions are achieved in a high synthetic input of fertilizer farming system (Nora, Nova & Saefur, 2023). Fertilizers have been widely used in many intensive cropping systems because of their low concentration in soils (0.5–5 g kg−1), but only a small fraction is available for plants (Lolt, Kolasa, Batten & Campbell 2011). This paper focused on the adoption of mixed-level factorial design to determine the effect of inorganic fertilizers on the yield of tomatoes. When an experiment is conducted with more than one independent variable, it is easy to exploit one predictor variable between subjects and within subjects. This scenario gives birth to a mixed-level factorial of experiments where factors at least one has a count of level which diverse from another factor. A mixed-level factorial experimental design technique can be used to determine the effect of different crops yield when soil amendment is in practice to improve soil nutrient for the soil to become more fertile for cultivation. Akra and Edet (2017) used the concept of factorial experiment to confound different organic fertilizers ABCDE (where A is animal manure, B is green manure, C is mineral manure, D is compost manure and E is ash manure) in different block sizes to obtain optimal yield.

Tomato (Solanum lycopersicum L.) is the foremost vegetable in the world in terms of production and consumption and has considerable nutritional benefits in addition to its economic importance. Tomato is the most popular vegetable growing at different parts of the world but it is sensitive to soil water deficit (Yang et al. 2022; Hou et al. 2020). It is not only being versatile because it is consumed fresh or processed but also because of its richness of beneficial phytochemicals such as phenols (Adegbola et al., 2019). Tomato yield is significantly affected due to soil moisture deficit at 50% field capacity (FC) compared to 100% FC (Chakma et al. 2021). Similarly, tomato fruit yield was reduced by 86−94% and water productivity by 79–92% at 50% FC assessed with 100% FC (Chakma et al., 2022). Marketable fruit yield of tomatoes decreased by 53–83% (Cantore at al., 2016).

Nitrogen is one of the most important nutrients required by tomatoes for better yield and quality because many physiological metabolic processes and the conformational structures of crops are related to nitrogen nutrient. Due to the high demand and importance of nitrogen for tomatoes, over-fertilization is still very common in traditional planting of tomatoes in order to achieve larger yield (Min, Zhang & Shi, 2012; Thompson, Incrocci & Ruijven, 2020). Consequently, proper management of nitrogen fertilization is essential for the development of tomato plants and the sustainability of the environment (Albornoz, 2016). The recommended nitrogen input for tomato is 250 kg ha−1 to maximize tomato yield and water productivity, while nitrogen input should be 150 kg ha−1 in order to maximize nitrogen use efficiency (Du et al., 2017). Jalpa et al. (2021) discovered that the recommended nitrogen application of 168 kg ha−1 is considered for plant and soil nitrogen recoveries, fruit and whole plant dry matter yields. However, Wang et al. (2015) found that the best tomato yield and comprehensive quality could be obtained with 574 kg N ha−1 under full and deficit irrigation. In order to achieve better soil nitrogen supply capacity and environmental benefits, the nitrogen input should be 225 kg ha−1 (Li et al., 2016).

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Phosphorus (P) deficiency has become one of the principal limiting factors for crop growth due to the loss of P nutrients caused by high temperatures and the fixation of P by iron and aluminum oxides in the soil (Lopez-Arredondo et al., 2014). More extensive root systems increase the contact area between the roots and the soil and are able to absorb most of the phosphorus fertilizer that remains in the soil (Taiz et al., 2017). The demand and low availability of rock phosphate as a source of P fertilizer and the increasing awareness of the negative environmental consequences of high P fertilizer input have also increased the interest in improving the efficiency of P acquisition and utilization by plants (Clements et al., 2016). Potassium (K), an essential macro-element for plant growth, is an activator of many enzymes that involve in carbon and nitrogen metabolism in plants (Oosterhuis et al., 2014). To oppose the negative effects of biotic and abiotic stresses, the plants endeavour to increase the antioxidants production (Wang et al., 2018). Kongjie et al. (2023) investigated how K fertilizers (K_Cl, K_S) affect the accumulations of soluble sugars and organic acids in tomato fruits.

Materials and Methods

Data were collected using secondary source approach and the source is: Akwa Ibom State Agricultural programme (AKSDEP). The experiment from the report were carried out with three different inorganic fertilizers such as Nitrogen (N), Phosphorous (P) and Potassium (K). Factorial experiments were conducted at two levels of Nitrogen (N), three levels of Phosphorous (P) and four levels of Potassium (K) concentration using randomized complete block design. The experiment was replicated three times and the layout design for data is presented in Table 1.

Table 1: The $2 \times 3 \times 4$ factorial treatment combinations for two levels of Nitrogen, three levels of Phosphorous and four levels of Potassium

N	P	K			
		1	2	3	4
1	1	$n_1 p_1 k_1$	$n_1 p_1 k_2$	$n_1 p_1 k_3$	$n_1 p_1 k_4$
	2	$n_1 p_2 k_1$	$n_1 p_2 k_2$	$n_1 p_2 k_3$	$n_1 p_2 k_4$
	3	$n_1 p_3 k_1$	$n_1 p_3 k_2$	$n_1 p_3 k_3$	$n_1 p_3 k_4$
2	1	$n_2 p_1 k_1$	$n_2 p_1 k_2$	$n_2 p_1 k_3$	$n_2 p_1 k_4$
	2	$n_2 p_2 k_1$	$n_2 p_2 k_2$	$n_2 p_2 k_3$	$n_2 p_2 k_4$
	3	$n_2 p_3 k_1$	$n_2 p_3 k_2$	$n_2 p_3 k_3$	$n_2 p_3 k_4$

Multiple Linear Model For Three-Factor Factorial Experiment

The multiple linear model for three-factor (Nitrogen (N), Phosphorous (P) and Potassium (K)) factorial experiment is given as:

$$Y_{ijlr} = \mu + N_i + P_j + K_l + (NP)_{ij} + (NK)_{il} + (PK)_{jl} + (NPK)_{ijl} + \ell_{ijlr} \begin{cases} i = 1, 2, \cdots, n \\ j = 1, 2, \cdots, p \\ l = 1, 2, \cdots, k \\ r = 1, 2, \cdots, v \end{cases} \quad (1)$$

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where Y_{ijlr} is the observation corresponding to the i^{th} level of factor N, j^{th} level of factor P and l^{th} level of factor K in the r^{th} replication, $N_i = i^{th}$ i^{th} level effect of factor N, $P_j = j^{th}$ level effect of factor P, $K_l = l^{th}$ level effect of factor K, $(NP)_{ij} = i^{th}$ and j^{th} levels of factor $N \times P$ interaction, $(NK)_{il} = i^{th}$ and l^{th} levels of factor $N \times K$ interaction, $(PK)_{jl} = j^{th}$ and l^{th} levels of factor $P \times K$ interaction, $(NPK)_{ijl} = i^{th}$, j^{th} and l^{th} levels of factor $N \times P \times K$ interaction, and ℓ_{ijlr} = random error term.

Model Assumptions

The assumptions for the model are:

(i) $\sum_i N_i = \sum_j P_j = \sum_l K_l = 0$ (ii) $\sum_{ij} NP_{ij} = \sum_{il} NK_{il} = \sum_{jl} PK_{jl} = 0$ (iii) $\sum_j NPK_{ijl} = 0$

Estimation of Model Parameter

To estimate the model parameters, least squares method is adopted. From Equation (1), we obtained:

$$Y_{ijlr} = \mu + N_i + P_j + K_l + (NP)_{ij} + (NK)_{il} + (PK)_{jl} + (NPK)_{ijl} + \ell_{ijlr}$$

$$\ell_{ijlr} = Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl} \qquad (2)$$

$$\sum_{ijlr}^{npkv} \ell^2_{ijlr} = \sum_{ijlr}^{npkv} \left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right)^2$$

Let $\sum_{ijlr}^{npkv} \ell^2_{ijlr} = L$, then

$$L = \sum_{ijlr}^{npkv} \left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right)^2 \qquad (3)$$

Differentiating Equation (3), w .r .t μ, N_i, P_j, K_l, NP_{ij}, NK_{il}, PK_{jl}, NPK_{ijl} and equating them to zero, we obtained:

$$\frac{\partial L}{\partial \mu} = -2\sum_{ijlr}^{npkv} \left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0 \qquad (4)$$

$$\sum_{ijlr}^{npkv} Y_{ijlr} - npkv\mu - pkv\sum_i N_i - nkv\sum_j P_j - npv\sum_l K_l - kv\sum_{ij} NP_{ij} - pv\sum_{il} NK_{il} - nv\sum_{jl} PK_{jl} - v\sum_{ijl} NPK_{ijl} = 0$$

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$$\sum_{ijlr}^{npkv} Y_{ijlr}^{2} - npkv\mu = 0$$

by applying the above assumptions.

$$\hat{\mu} = \frac{1}{npkv}\sum_{ijlr}^{npkv} Y_{ijlr}^{2} = \bar{Y}_{....} \tag{5}$$

$$\frac{\partial L}{\partial N_i} = -2\sum_{jlr}^{pkv}\left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0 \tag{6}$$

$$= \sum_{i}^{n} Y_{i...} - pkv\mu - pkvN_i - kv\sum_{j} P_j - pv\sum_{l} K_l - kv\sum_{ij} NP_{ij} - pv\sum_{il} NK_{il} - v\sum_{jl} PK_{jl} - v\sum_{ijl} NPK_{ijl} = 0$$

$$\sum_{i}^{n} Y_{i...} - pkv\mu - pkvN_i = 0 \Rightarrow \hat{N}_i = \frac{1}{pkv}\sum_{i}^{n} Y_{i...} - \hat{\mu} \tag{7}$$

$$\frac{\partial L}{\partial P_j} = -2\sum_{ilr}^{nkv}\left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0 \tag{8}$$

$$\sum_{j=1}^{p} Y_{.j..} - nkv\mu - kv\sum_{i} N_i - nkvP_j - nv\sum_{l} K_l - kv\sum_{ij} NP_{ij} - v\sum_{il} NK_{il} - nv\sum_{jl} PK_{jl} - v\sum_{ijl} NPK_{ijl} = 0$$

$$\sum_{j=1}^{p} Y_{.j..} - nkv\mu - nkvP_j = 0 \quad \Rightarrow \hat{P}_j = \frac{1}{nkv}\sum_{j=1} Y_{.j..} - \hat{\mu} \tag{9}$$

$$\frac{\partial L}{\partial K_l} = -2\sum_{ijr}^{npv}\left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0$$

(10)

$$\sum_{l=1}^{k} Y_{..l.} - npv\mu - pv\sum_{i} N_i - nv\sum_{j} P_j - npvK_l - v\sum_{ij} NP_{ij} - pv\sum_{il} NK_{il} - nv\sum_{jl} PK_{jl} - v\sum_{ijl} NPK_{ijl} = 0$$

$$\sum_{l=1}^{k} Y_{..l.} - npv\mu - npvK_l = 0 \quad \Rightarrow \hat{K}_l = \frac{1}{npv}\sum_{l=1} Y_{..l.} - \hat{\mu}$$

(11)

$$\frac{\partial L}{\partial NP_{ij}} = -2\sum_{lr}^{kv}\left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0$$

(12)

$$\sum_{ij=1}^{np} Y_{ij..} - kv\mu - kvN_i - kvP_j - v\sum_{l} K_l - kvNP_{ij} - v\sum_{il} NK_{il} - v\sum_{jl} PK_{jl} - v\sum_{ijl} NPK_{ijl} = 0$$

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$$\sum_{ij=1}^{np} Y_{ij..} - kv\mu - kvN_i - kvP_j - kvNP_{ij} = 0 \quad \Rightarrow \hat{N}\hat{P}_{ij} = \frac{1}{kv}\sum_{ij} Y_{ij..} - \hat{\mu} - \hat{N}_i - \hat{P}_j$$

(13)

$$\frac{\partial L}{\partial NK_{il}} = -2\sum_{jr}^{pv}\left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0$$

(14)

$$\sum_{il=1}^{nk} Y_{i.l.} - pv\mu - pvN_i - v\sum_j P_j - pvK_l - kv\sum_{ij} NP_{ij} - pvNK_{il} - v\sum_{jl} PK_{jl} - v\sum_{ijl} NPK_{ijl} = 0$$

$$\sum_{il=1}^{nk} Y_{i.l.} - pv\mu - pvN_i - pvK_l - pvNK_{il} = 0 \quad \Rightarrow \hat{N}\hat{K}_{il} = \frac{1}{pv}\sum_{il=1}^{nk} Y_{i.l.} - \hat{\mu} - \hat{N}_i - \hat{K}_l$$

(15)

$$\frac{\partial L}{\partial PK_{jl}} = -2\sum_{ir}^{nv}\left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0$$

(16)

$$\sum_{jl=1}^{pk} Y_{.jl.} - nv\mu - v\sum_i N_i - nvP_j - nvK_l - kv\sum_{ij} NP_{ij} - v\sum_{il} NK_{il} - nvPK_{jl} - v\sum_{ijl} NPK_{ijl} = 0$$

$$\sum_{jl=1}^{pk} Y_{.jl.} - nv\mu - nvP_j - nvK_l - nvPK_{jl} = 0 \quad \Rightarrow \hat{P}\hat{K}_{jl} = \frac{1}{nv}\sum_{jl=1}^{pk} Y_{.jl.} - \hat{\mu} - \hat{P}_j - \hat{K}_l$$

(17)

$$\frac{\partial L}{\partial NPK_{jl}} = -2\sum_{r}^{v}\left(Y_{ijlr} - \mu - N_i - P_j - K_l - (NP)_{ij} - (NK)_{il} - (PK)_{jl} - (NPK)_{ijl}\right) = 0$$

$$\sum_{ijl=1}^{npk} Y_{ijl.} - v\mu - vN_i - vP_j - vK_l - vNP_{ij} - vNK_{il} - vPK_{jl} - vNPK_{ijl} = 0$$

$$\hat{N}\hat{P}\hat{K}_{ijl} = \frac{1}{v}\sum_{ijl=1}^{npk} Y_{ijl.} - \hat{\mu} - \hat{N}_i - \hat{P}_j - \hat{K}_l - \hat{N}\hat{P}_{ij} - \hat{N}\hat{K}_{il} - \hat{P}\hat{K}_{jl}$$

(18)

Sums of Squares for the Design

The computing formulas for the sums of squares are given below:

(1) Total sum of squares is found in the usual way as:

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$$SS_T = \sum_{ijlr=1}^{npkv} Y_{ijlr}^2 - \frac{Y_{....}^2}{npkr}$$

(19)

The sum of square for main effects are found from the totals for factors $N(Y_{i...}), P(Y_{.j..})$ and $K(Y_{..l.})$ as follows:

$$SS_N = \frac{1}{pkr} \sum_{i=1}^{n} Y_{i...}^2 - \frac{Y_{....}^2}{npkr}$$

(20)

$$SS_P = \frac{1}{nkr} \sum_{j=1}^{p} Y_{.j..}^2 - \frac{Y_{....}^2}{npkr}$$

(21)

$$SS_K = \frac{1}{npr} \sum_{l=1}^{k} Y_{..l.}^2 - \frac{Y_{....}^2}{npkr}$$

(22)

$$SS_{NP} = \frac{1}{kr} \sum_{ij=1}^{np} Y_{ij..}^2 - \frac{Y_{....}^2}{npkr} - SS_N - SS_P \quad \Rightarrow SS_{subtotal} - SS_N - SS_P$$

(23)

$$SS_{NK} = \frac{1}{pr} \sum_{il=1}^{nk} Y_{i.l.}^2 - \frac{Y_{....}^2}{npkr} - SS_N - SS_K \quad \Rightarrow SS_{subtotal} - SS_N - SS_K$$

(24)

$$SS_{PK} = \frac{1}{nr} \sum_{jl=1}^{pk} Y_{.jl.}^2 - \frac{Y_{....}^2}{npkr} - SS_P - SS_K \quad \Rightarrow SS_{subtotal} - SS_P - SS_K$$

(25)

$$SS_T = \sum_{ijl=1}^{npk} Y_{ijl.}^2 - \frac{Y_{....}^2}{npkr} - SS_N - SS_P - SS_K - SS_{NP} - SS_{NK} - SS_{PK}$$

(26)

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Analysis of Variance Table for the Experiment

The general ANOVA Table illustrating three-factor factorial design is given in Table 2.

Table 2: ANOVA Table for a Three-Factor Factorial Design with r Replicates

S/V	df	SS	MS	F
Block	$r-1$	SS_{rep}	$\frac{MS_{rep}}{r-1}$	$\frac{MS_{rep}}{MS_E}$
Treatment				
N	$n-1$	SS_N	$\frac{MS_N}{n-1}$	$\frac{MS_N}{MS_E}$
P	$p-1$	SS_P	$\frac{MS_P}{p-1}$	$\frac{MS_P}{MS_E}$
K	$k-1$	SS_K	$\frac{MS_K}{k-1}$	$\frac{MS_K}{MS_E}$
NP	$(n-1)(p-1)$	SS_{NP}	$\frac{MS_{NP}}{(n-1)(p-1)}$	$\frac{MS_{NP}}{MS_E}$
NK	$(n-1)(k-1)$	SS_{NK}	$\frac{MS_{NK}}{(n-1)(k-1)}$	$\frac{MS_{NK}}{MS_E}$
PK	$(p-1)(k-1)$	SS_{PK}	$\frac{MS_{PK}}{(p-1)(k-1)}$	$\frac{MS_{PK}}{MS_E}$
NPK	$(n-1)(p-1)(k-1)$	SS_{NPK}	$\frac{MS_{NPK}}{(n-1)(p-1)(k-1)}$	$\frac{MS_{NPK}}{MS_E}$
Error	$npk(r-1)$	SS_E	$\frac{MS_E}{npk(r-1)}$	
Total	$npkr-1$	SS_T		

RESULTS

An experiment was conducted using mixed level factorial experimental technique. The experiment was replicated three times, which gives the total number of 72 observations. Mean yield of tomato fruit was tested with two levels of Nitrogen, three levels of Phosphorus and four levels of Potassium in a randomized complete block design. The data obtained from the experiment is presented in Table 3 and the result of analysis is shown in Table 4. The normality test is illustrated in Fig. 1, while main effect and interaction components are presented in Fig. 2 and Fig. 3.

Table 3: Mean Yield of Potatoes Tested with $2 \times 3 \times 4$ Levels of Nitrogen, Phosphorous and Potassium in a RCBD

Treatment			Replication (blocks)			Treatment totals
N	P	K	I	II	III	
		1	3	2	4	9
	1	2	5	7	6	18
	3		4	9	9	22

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	4		2	3	3	8
1		1	3	6	4	13
	2	2	5	8	8	21
	3		6	9	9	24
	4		4	3	3	11
		1	3	6	4	13
	3	2	8	5	2	15
	3		7	7	7	21
	4		7	8	4	19
		1	11	11	4	31
	1	2	14	13	12	39
	3		16	14	17	47
	4		10	8	12	30
		1	7	8	8	23
2	2	2	11	9	7	27
	3		16	18	16	50
	4		10	9	14	33
		1	9	8	10	27
	3	2	12	14	11	37
	3		14	16	13	43
	4		10	12	11	33
Block totals			197	214	203	614

Table 4: Analysis of Variance Table for the Three Inorganic Fertilizers

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	25	1080.14	43.206	16.59	0.000
Blocks	2	6.19	3.097	1.19	0.314
Linear	6	969.11	161.519	62.02	0.000
N	1	709.39	709.389	272.37	0.000
P	2	0.78	0.389	0.15	0.862
K	3	258.94	86.315	33.14	0.000
2-Way Interactions	11	71.83	6.530	2.51	0.015
N*P	2	14.78	7.389	2.84	0.069
N*K	3	24.50	8.167	3.14	0.034
P*K	6	32.56	5.426	2.08	0.074
3-Way Interactions	6	33.00	5.500	2.11	0.070
N*P*K	6	33.00	5.500	2.11	0.070
Error	46	119.81	2.604		
Total	71	1199.94			

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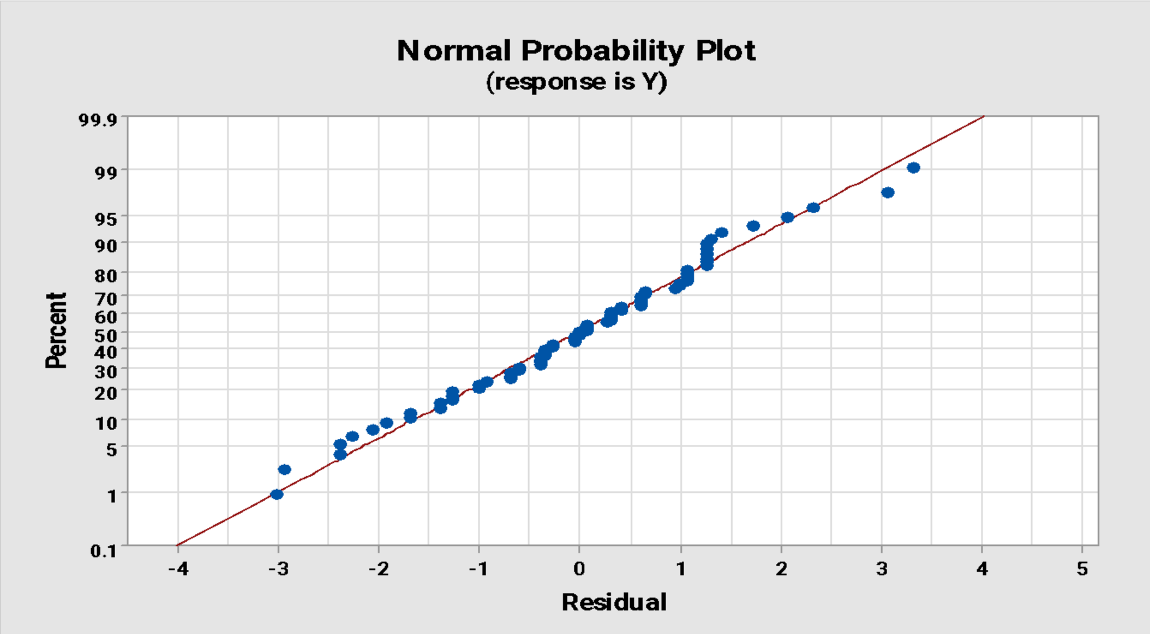

Figure 1: Graph showing the normality of the data

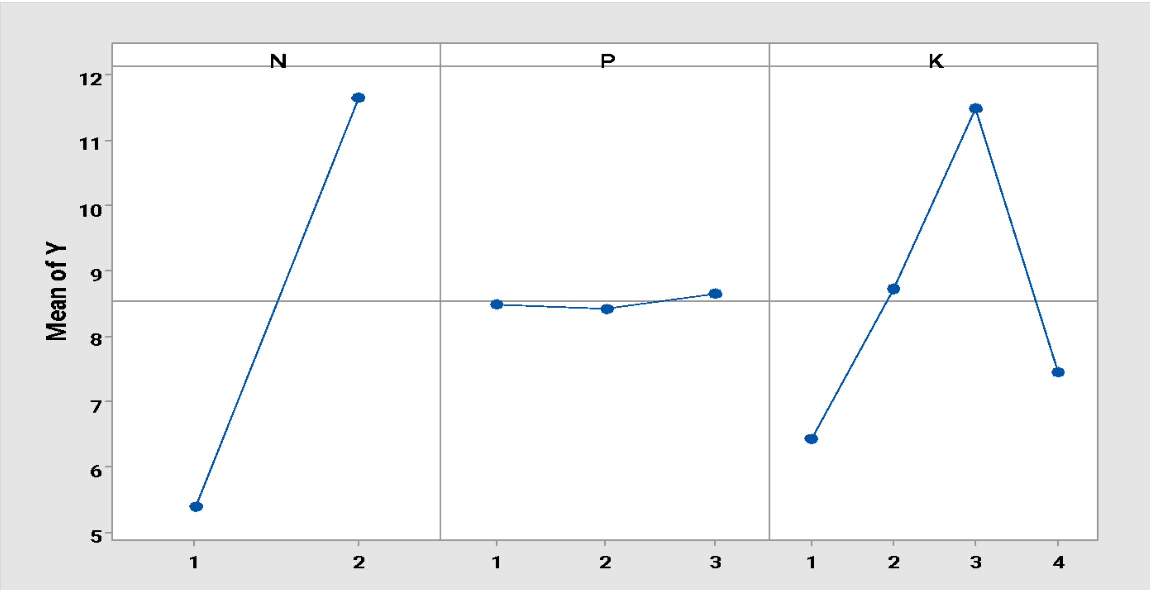

Figure 2: Graph of main effect for the factor's concentration

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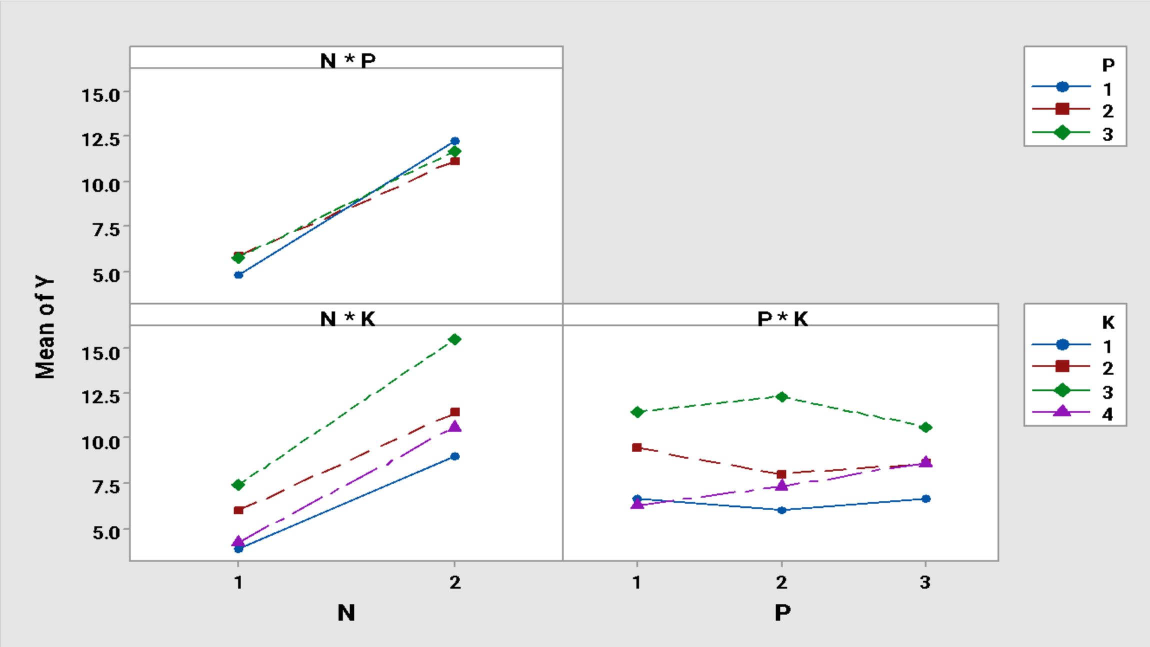

Figure 3: Graph of the effect of yield for factors interaction

DISCUSSION OF RESULTS

Data were collected using secondary source of data collection and the experiment was carried out with three different inorganic fertilizers namely Nitrogen (N), Phosphorous (P) and Potassium (K). Factorial experiment was conducted at two levels of Nitrogen (N), three levels of Phosphorous (P) and four levels of Potassium (K) concentration using randomized complete block design. The result showed that the effects of the three inorganic fertilizers are not the same at each level of concentration reported in Table 4 and visualized in Fig. 2 and at 5% level of significance. Fig. 1 shows that the data are normally distributed and it accurately fitted the model. The analysis for the factorial component revealed that the NK concentration is significant which implies that the effect of Nitrogen (N) depends on the levels of Potassium (K) and vice versa. The NP and PK concentrations are not significant indicating that the effect of Nitrogen (N) does not depend on the levels of Phosphorus and the same occurs with Phosphorus and Potassium. (See Fig. 3.) Also, the interaction effects for the three components of NPK are not significant; this shows that the effect of the three inorganic fertilizers does not depend on the level of each other.

CONCLUSION

The result revealed that some of the two inorganic fertilizers type are significant while one is not, which implies that the effect of the three types of inorganic fertilizers varies in yields. Two-factor interaction for two fertilizers combination (NP and PK) and NPK interaction are not significant while NK interaction is significant. This is an indication that the effect of Nitrogen (N) does not depend on the level of Phosphorus (P) and the same occurs with Phosphorus (P) and Potassium (K). Despite the variation in the effect of the three components, the analysis has proven that Phosphorus (P) is the optimal nutrient that improves soil fertility than the other two inorganic fertilizers.

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