Statistical Investigation of the Effect of Soil Compost and Rock Phosphate on the Growth Characteristics of Oil Palm Tree Using Factorial Model.

J.I. Mbegbu[1] and F.O. Chete[2*]

[1]Department of Mathematics, University of Benin, Benin City, Nigeria.
[2]Department of Computer Science, University of Benin, Benin City, Nigeria.

E-mail: odichet@yahoo.com

ABSTRACT

Statistical investigation of the effect of soil compost (Factor A) and rock phosphate (Factor B) on the growth characteristics of oil palm tree was carried out at 5% level of significance. Consequently, the results showed that there are significant effects of these factors on the growth characteristics of oil palm tree. There is also a significant interaction of effects of soil compost and rock phosphate on the growth characteristics.

(Keywords: factorial, experiment, model, soil compost, rock phospate, growth, oil palm tree)

INTRODUCTION

Much of our knowledge about products and processes in engineering, agriculture, and scientific discipline are derived from experimentation (Hill and Wiles, 1975). Experimental design techniques become extremely important in such situations to develop new products and process (Pratt and Tort, 1990). Of all forms of the layout of experimental design, factorial design is most valued (Montgomery, 1991) as it helps us to test the effect of more than one factor on the response variable or to test the effect of the interaction effects of the variable on the responses (Box et al (2005); Box (1990); Hunter (1994)).

In this work, 4x5 factorial design shall be employed to investigate the effect of soil compost and rock phosphate on the growth characteristics of oil palm tree. We shall also test whether there is a significant interaction effect between the soil compost and rock phosphate on the growth characteristics of oil palm tree. The soil compost (factor A) and rock phosphate (factor B) are measured at four and five levels, respectively.

The model describing the 4x5 factorial experiment using three replications is given as:

$$X_{ijk} = \mu + \alpha_i + \beta_j + \phi_{ij} + \in_{ijk}, i = 1(1)4;\ j = 1(1)5, k = 1(1)3 \quad \textbf{(1)}$$

where,

$X_{ijk} \equiv response\,(value)\ from\ i^{th}\ level\ of\ soil\ compost\ and\ j^{th}\ level\ of\ rock\ phosphate\ at\ k^{th}\ replication$

$\mu \equiv Overall\ mean\ value$

$\alpha_i \equiv Main\ effect\ of\ soil\ compost\ at\ i^{th}\ level$

$\beta_j \equiv Main\ effect\ of\ rock\ phosphate\ at\ j^{th}\ level$

$\phi_{ij} \equiv interaction\ effect\ of\ soil\ compost\ and\ rock\ phosphate\ at\ (i,j)^{th}\ level$

$\in_{ijk} \approx N(o, \sigma^2)\ \ is\ the\ random\ error$

METHODS AND MATERIAL

Under the assumption that $\in_{ijk} \approx N(o, \sigma^2)$ and exploiting model (1.1), the estimates of the parameters μ, α_i, β_j and ϕ_{ij} are (Box et al, 2005).

$$\hat{\mu} = \frac{1}{60}\sum_{i=1}^{4}\sum_{j=1}^{5}\sum_{k=1}^{3} X_{ijk}$$

$$\hat{\alpha}_i = \frac{1}{15}\sum_{j=1}^{5}\sum_{k=1}^{3} X_{ijk} - \hat{\mu}\ ; \qquad i = 1(1)4$$

$$\hat{\beta}_j = \frac{1}{12}\sum_{i=1}^{4}\sum_{k=1}^{3} X_{ijk} - \hat{\mu}\ ; \qquad j = 1(1)5$$

$$\hat{\phi}_{ij} = \frac{1}{3}\sum_{k=1}^{3}\left(X_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j\right)\ ; \qquad i = 1(1)4,\ j = 1(1)5,\ i \neq j$$

We formulate the test hypotheses as follows:

a) $H_o: \alpha_i = 0$, for $i = 1(1)4$ (No mean effect of soil compost on the growth characteristics of oil palm tree)

Versus $H_i: \alpha_i \neq 0$, for at least one value of i (There is mean effect of soil compost on the growth characteristics of oil palm tree)

b) $H_o: \beta_j = 0$, for $j = 1(1)5$ (No mean effect of rock phosphate on the growth characteristics of oil palm tree)

Versus $H_i: \beta_j \neq 0$, for at least one value of j (There is mean effect of rock phosphate on the growth characteristics of oil palm tree)

c) $H_o: \phi_{ij} \neq 0$, for at least one (i, j) (There is interaction effect)

Under the null hypotheses (Cochram and Cox, 1957) in (a), (b) and (c), and for $\in_{ijk} \approx N(o, \sigma^2)$, the F-statistics for the soil compost (Factor A), rock phosphate (Factor B) and interaction (AB) are:

$$F_A = \frac{MSS_A}{MSE}, F_B = \frac{MSS_B}{MSE}, and\ F_{AB} = \frac{MSS_{AB}}{MSE} \qquad \textbf{(2)}$$

respectively, where MSS_A, MSS_B, MSS_{AB} and MSE are the mean sum of squares for factor A, factor B, interaction AB and error respectively.

These statistics F_A, F_B and F_{AB} are F-distributed with degree of freedom ($v_1 = 3$, $v_2 = 40$), ($v_1 = 4$, $v_2 = 40$), and ($v_1 = 12$, $v_2 = 40$), respectively. Thus, the analysis of variance (ANOVA) table associated with the 4 x 5 factorial design is given in Table 1.

Table 1: ANOVA table for 4 x 5 Factorial Design.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Soil compost (Factor A)	3	SS_A	$MSS_A = \frac{SS_A}{3}$	$F_A = \frac{MSS_A}{MSE}$
Rock phosphate (Factor B)	4	SS_B	$MSS_B = \frac{SS_B}{4}$	$F_B = \frac{MSS_B}{MSE}$
Interaction (AB)	12	SS_{AB}	$MSS_{AB} = \frac{SS_{AB}}{12}$	$F_{AB} = \frac{MSS_{AB}}{MSE}$
Error	40	SSE	$MSE = \frac{SSE}{40}$	

DATA COLLECTION

The data for this analysis were collected from Department of Statistics, Nigeria Institute for Oil Palm Research (NIFOR) at Benin City, Edo State, Nigeria. The data are on a factorial experiment conducted on the effect of two factors namely soil compost (Factor A) at four levels and rock phosphate (Factor B) at five levels on the growth characteristics of oil palm tree which of course are the responses.

The growth characteristics measured are as follows: Number of leaves (LEF), Height (HGT), Girth (GTH), Fresh Weight leaves (FWL), Fresh weight root (FWR), Fresh weight total (FWT), Dry weight leaves (DWL), Dry weight root (DWR) and Dry weight total (DWT).

Table 2: Presentation of Data.

Soil compost	Rock phosphate	REPLICATION 1									REPLICATION 2									REPLICATION 3								
		LEF	HGT	GTH	FWL	FWR	FWT	DWL	DWR	DWT	LEF	HGT	GTH	FWL	FWR	FWT	DWL	DWR	DWT	LEF	HGT	GTH	FWL	FWR	FWT	DWL	DWR	DWT
0	0	11	61	11	95.6	83	178.6	24.9	15.5	40.4	12	67	11.5	89.4	74.4	163.8	25.7	15.2	40.9	12	58	11	77.5	36.8	114.3	27.2	8.8	30
	50	11	61	11	96.1	49.4	145.3	29.7	13.1	42.8	11	56	9	75	57.2	132.2	21.9	15.5	37.4	11	57	10.5	67.6	42.8	110.4	19.9	11.8	31.7
	100	11	50	10.5	70.4	46.4	116.8	18.3	8.6	26.9	12	60	9.5	91.4	54.3	145.7	24.5	10.5	25	12	70	12	71.7	44.8	116.5	19.7	11.9	31.6
	150	13	58	11.5	96.7	69.9	166.6	26.7	14.3	41	12	69	10.5	88.3	69.5	157.8	24.9	13.5	38.4	12	63	13.5	90.4	67	157.4	25.2	17.2	42.4
	200	13	69	8	58.9	54	112.9	15.7	9.4	25.3	12	61	10	78.6	56.5	144.1	26.1	12.2	38.3	12	61	13	82.3	66.2	148.5	24	16	40
	0	11	70	13	91.8	90.9	182.7	22.7	17.4	40.1	13	76	15	15.4	86.5	240.7	45.6	16.2	61.8	13	63	11	97.3	45.8	143.5	25.8	11.8	.37.6
	50	12	71	12	86	47.1	133.1	27.9	13.6	41.5	13	61	14	107.1	65.5	172.6	33	16.1	49.1	11	70	13	112.6	66.8	179.4	41.1	16.4	57.5
	100	13	60	13	89.3	91.8	181.1	25.4	17.8	43.2	11	66	12	92.6	67.8	160.4	26.9	16.9	43.8	12	66	13.5	108.5	72.2	108.7	28	15.6	43.6
	150	13	62	13.5	115.3	97.5	212.8	32.2	18.2	50.4	13	64	12	101.1	72.6	173.7	26.4	16.3	42.7	11	61	11.5	101.7	79.6	181.3	30.9	18.5	49.4
	200	12	62	11.5	86.2	95.8	182	23.7	19.4	43.1	11	56	11	80.2	60.7	140.9	21.7	13.2	34.9	12	64	10	71	50.5	121.5	20.4	12.9	33.3
10	0	12	76	14	153.5	129.3	282.8	40.2	24.4	64.2	13	78	13	158.2	84.3	242.5	46.9	18.1	65	13	57	12	92.5	62.1	154.6	28.1	17.7	45.8
	50	12	73	13.5	135.2	96.6	231.8	37.7	21.6	59.3	13	78	11	113.3	51.1	164.4	38.4	12.6	51	13	80	14.5	169.6	95.5	265.1	60.3	24.9	85.2
	100	12	71	13	115.6	65.5	181.1	42.8	7.5	50.3	11	74	13	105.6	69.3	174.9	30.8	14.5	45.3	11	74	12	100.5	68.1	168.6	31.8	17.5	49.3
	150	12	61	10	104.1	97.7	201.8	29.2	19.8	49	12	55	14	96.6	57.7	154.3	26.3	13.4	39.7	13	64	11	79	54.6	133.6	23	13.6	36.6
	200	10	63	11.5	80.3	47.5	127.8	24.5	10.6	35.1	12	64	10	78.7	73.6	152.3	23.6	16	39.6	10	67	7	64.6	51.8	116.4	18.8	13.2	32
	0	13	52	11	67.7	49.6	117.3	18.8	12.9	31.7	10	60	10	66.8	57.1	123.9	18	11.4	29.4	11	56	12	93.8	88.1	181.9	30	18.6	48.6
	50	12	57	11	62.1	46.8	108.9	18.1	9.9	28	11	61	12	81.6	96.1	177.7	21	24.9	45.9	11	55	10	69.3	79.1	148.4	22	21.1	43.1
	100	12	58	12	80.6	80.5	161.1	25.5	17.1	42.6	11	65	14	70.5	108	178.9	21.1	24.2	45.3	11	58	9.5	.87.4	82.9	170.3	26.8	20.9	47.7
	150	12	65	10.5	68.3	56.5	124.8	**	**	**	11	53	14	76	105	181.3	21.3	21.2	42.5	13	55	10	86.6	88.4	175	25.7	23.6	49.3
	200	11	62	13	84.5	63.2	147.7	23.4	15.4	38.8	12	68	11	74.4	89	163.4	23.5	18.7	42.2	12	59	9.5	88.4	141.1	229.5	27	30	57
20	0	12	76	14	153.5	129.3	282.8	40.2	24.4	64.2	13	78	13	158.2	84.3	242.5	46.9	18.1	65	13	57	12	92.5	62.1	154.6	28.1	17.7	45.8
	50	12	73	13.5	135.2	96.6	231.8	37.7	21.6	59.3	13	78	11	113.3	51.1	164.4	38.4	12.6	51	13	80	14.5	169.6	95.5	265.1	60.3	24.9	85.2
	100	12	71	13	115.6	65.5	181.1	42.8	7.5	50.3	11	74	13	105.6	69.3	174.9	30.8	14.5	45.3	11	74	12	100.5	68.1	168.6	31.8	17.5	49.3
	150	12	61	10	104.1	97.7	201.8	29.2	19.8	49	12	55	14	96.6	57.7	154.3	26.3	13.4	39.7	13	64	11	79	54.6	133.6	23	13.6	36.6
	200	10	63	11.5	80.3	47.5	127.8	24.5	10.6	35.1	12	64	10	78.7	73.6	152.3	23.6	16	39.6	10	67	7	64.6	51.8	116.4	18.8	13.2	32
	0	13	52	11	67.7	49.6	117.3	18.8	12.9	31.7	10	60	10	66.8	57.1	123.9	18	11.4	29.4	11	56	12	93.8	88.1	181.9	30	18.6	48.6
	50	12	57	11	62.1	46.8	108.9	18.1	9.9	28	11	61	12	81.6	96.1	177.7	21	24.9	45.9	11	55	10	69.3	79.1	148.4	22	21.1	43.1
	100	12	58	12	80.6	80.5	161.1	25.5	17.1	42.6	11	65	14	70.5	108	178.9	21.1	24.2	45.3	11	58	9.5	.87.4	82.9	170.3	26.8	20.9	47.7
	150	12	65	10.5	68.3	56.5	124.8	**	**	**	11	53	14	76	105	181.3	21.3	21.2	42.5	13	55	10	86.6	88.4	175	25.7	23.6	49.3
	200	11	62	13	84.5	63.2	147.7	23.4	15.4	38.8	12	68	11	74.4	89	163.4	23.5	18.7	42.2	12	59	9.5	88.4	141.1	229.5	27	30	57
30	0	13	52	11	67.7	49.6	117.3	18.8	12.9	31.7	10	60	10	66.8	57.1	123.9	18	11.4	29.4	11	56	12	93.8	88.1	181.9	30	18.6	48.6
	50	12	57	11	62.1	46.8	108.9	18.1	9.9	28	11	61	12	81.6	96.1	177.7	21	24.9	45.9	11	55	10	69.3	79.1	148.4	22	21.1	43.1
	100	12	58	12	80.6	80.5	161.1	25.5	17.1	42.6	11	65	14	70.5	108	178.9	21.1	24.2	45.3	11	58	9.5	.87.4	82.9	170.3	26.8	20.9	47.7
	150	12	65	10.5	68.3	56.5	124.8	**	**	**	11	53	14	76	105	181.3	21.3	21.2	42.5	13	55	10	86.6	88.4	175	25.7	23.6	49.3
	200	11	62	13	84.5	63.2	147.7	23.4	15.4	38.8	12	68	11	74.4	89	163.4	23.5	18.7	42.2	12	59	9.5	88.4	141.1	229.5	27	30	57

Analysis of Data

The analysis of data was done using statistical package SAS/STAT. The results are shown in the tables below:

Table 3: ANOVA FOR LEF.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Soil compost (factor A)	3	2.33	0.78	1.17
Rock phosphate (factor B)	4	4.00	1.00	1.50
Interaction (AB)	12	11.33	0.94	1.42

Table 4: ANOVA FOR HGT.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	858.00	286.00	10.15
Factor B: Rock phosphate	4	135.60	33.90	1.20
Interaction AB	12	730.00	60.83	2.16

Table 5: ANOVA FOR GTH.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	21.75	7.25	3.04
Factor B: Rock phosphate	4	20.96	5.24	2.19
Interaction AB	12	22.61	1.88	0.79

Table 6: ANOVA FOR FWL.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	10240.51	3413.50	12.88
Factor B: Rock phosphate	4	4276.99	1069.25	4.03
Interaction AB	12	7633.63	636.14	2.40

Table 7: ANOVA FOR FWR.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	4426.04	1475.35	3.63
Factor B: Rock phosphate	4	766.24	191.56	0.47
Interaction AB	12	6412.72	534.39	1.32

Table 8: ANOVA FOR FWT.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	16570.97	5523.66	4.94
Factor B: Rock sulphate	4	5463.76	1365.94	1.22
Interaction AB	12	23141.04	1928.42	1.72

Table 9: ANOVA FOR DWL.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	1001.10	333.70	9.65
Factor B: Rock phosphate	4	545.40	136.35	3.94
Interaction AB	12	873.17	72.76	2.10

Table 10: ANOVA FOR DWR.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	311.25	103.75	6.46
Factor B: Rock phosphate	4	45.31	11.33	0.71
Interaction AB	12	256.98	21.42	1.33

Table 11: ANOVA FOR DWT.

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-value
Factor A: Soil compost	3	1598.63	532.88	8.32
Factor B: Rock phosphate	4	609.25	152.31	2.38
Interaction AB	12	1903.16	158.60	2.48

Table 12: F-value and F-table at 5% level of Significance.

		LEF	HGT	GTH	FWL	FWR	FWT	DWL	DWR	DWT
Sources of variation	**F table**	**F-value**	**F-value**	**F-value**	**F-value**	**F-value**	**F-value**	**F-value**	**F-value**	**F-value**
Factor A: Soil compost	2.84	1.17	10.15	3.04	12.88	3.63	4.94	9.65	6.46	8.32
Factor B: Rock phosphate	2.61	1.50	1.20	2.19	4.03	0.47	1.22	3.94	0.71	2.38
Interaction AB	1.92	1.42	2.16	0.79	2.40	1.32	1.72	2.10	1.33	2.48

Table 13: Statistical Decision at 5% level of Significance.

	DECISIONS								
	LEF	**HGT**	**GTH**	**FWL**	**FWR**	**FWT**	**DWL**	**DWR**	**DWT**
Factor A: Soil compost	Accept H_o	Reject H_o	Reject H_o	Reject H_o	Reject H_o	Reject H_o	Reject H_o	Reject H_o	Reject H_o
Factor B: Rock phosphate	Accept H_o	Accept H_o	Accept H_o	Reject H_o	Accept H_o	Accept H_o	Reject H_o	Accept H_o	Accept H_o
Interaction AB	Accept H_o	Reject H_o	Accept H_o	Reject H_o	Accept H_o	Accept H_o	Reject H_o	Accept H_o	Reject H_o

DISCUSSION AND CONCLUSION

Based on the analysis, we are 95% confident that:

i. The soil compost had a significant effect on HGT, GTH, FWR, DWR, DWT, DWL. FWT and FWL.

ii. The rock phosphate had a significant effect on FWL and DWL.

iii. The soil compost had no significant effect on LEF.

iv. The rock phosphate interaction effect of soil compost and rock phosphate on LEF, HGT, GTH, FWR, FWT, DWR and DWT.

v. There is significant interaction effect of soil compost and rock phosphate on HGT, FWL, DWL and DWT.

vi. There is no significant interaction effect of soil compost and rock phosphate on LEF, GTH, FWR, FWT and DWR.

REFERENCES

1. Box, G.E.P. 1990. "Do Interactions Matter?". *Quality Eng*. 2:365-369.

2. Box, G.E.P., J.S. Hunter, and W.G. Hunter. 2005. *Statistics for Experimenters: Design, Innovation and Discovery, 2nd Edition*. John Wiley and Sons: New York, NY.

3. Cochran, W.G. and G. Cox. 1957. *Experimental Design*. John Wiley and Sons: New York, NY.

4. Hill, W.J. and R.A. Wiles. 1975. "Plant Experimentation (PLEX)". *J. Qual. Tech.* 7:115-122.

5. Hunter, P. 1994. "Interactions: Ignore them at Your Own Risk". *J. Qual. Tech.* 21:174-178.

6. Montgomery, D.C. 1984. *Design and Analysis of Experiments, 2nd Edition*. John Wiley and Sons: New York, NY.

7. Pratt, A. and X. Tort. 1990. "Case Study: Experimental Design in a Pet Food Manufacturing Company". *Quality Eng.* 3(1): 59-73.

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