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Analytical Study on the Optimization of Crop Nutrients Using the Randomized Complete Block Design Model

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Abstract— *This paper attempts to evaluate the application of randomized complete block design (RCBD) model in improving crop production. Data for the study was sourced from an experiment that lasted for three weeks. The data were analyzed using SPSS package. After exploring the concept of the RCBD technique, the response of the soil nutrient to the treatment of the various manure types revealed that, there was a significant difference on crop yield with respect to the type of manure treatment applied at P < 0.05, [F 39.719, P = 0.000]. Post Hoc pairwise comparison using the Tukey HSD test method indicated that, the mean score for poultry waste treatment effect was significantly different from every other manure type, also the mean score for NPK fertilizer was significantly different from the effect of palm waste, cattle dung, green manure and the control effects. Collectively, the findings of the study revealed that poultry waste application is effective in improving soil nutrients on the growing of crops.*

Keywords— *Randomized complete block design, two-way ANOVA test, multiple comparison tests, SPSS, optimization, Tukey HSD.*

I. Introduction

Whenever we want to allocate the available limited resources for various competing activities for achieving our desired objective, the issue of what to do how to do it becomes a bugging problem. For managers, the problem of cost minimization is their top priority and hence they need help in making optimal decision by assigning/allocating resources at the least cost level. It is the manager's ability to make the best decision in presence of uncertainty that makes him a good practicing manager. Over the years, there have been postulated statistical methods in enhancing decision making process in various fields of endeavor including agriculture. One of the known methods that have proved its worth in research and problem solving situations is the Analysis of variance (ANOVA).

In various research fields, there have being a growing tendencies in evaluation differences between three or more groups of means. A key statistical test in research fields including, agriculture, education, biology, economics and psychology, ANOVA is useful for analyzing datasets with more than two groups. It allows comparisons to be made between three or more groups of data.

Fraiman and Fraiman (2018) used the ANOVA model to analyze a statistical comparison of brain networks and the associated detection and identification problems. They tested network differences between groups with ANOVA test. Hajihassani, (2013) in his study developed a Latin square design of ANOVA to model the factors affecting banking industry efficiency. The aim of his study was to investigate the influence of time, type banks and financial ratios of efficiency accepted in Tehran stock exchange banks. His study concluded that time and type bank do not the same effect on the efficiency of banks but financial ratios have the same effect on the efficiency banks at $\alpha = 0.05$.

Bharathi and Natarajan (2010) used the ANOVA model to examine cancer classification bioinformatics data. The study was aimed at finding the smallest set of genes that can ensure highly accurate classification of cancer from micro array data by using supervised machine learning algorithms.

Rangriz et al., (2012) presented performance evaluation of Iran cement companies based on A Hp and Topsis methods. Purpose of his study is representing manners, which select the problem and solve ranking optimally by multi criteria decision-making methods and by high ability using the ANOVA one way model. His findings revealed that the ANOVA result was efficient in distinguishing the most performed cement company in terms of production volume.

Resource allocation is an analysis of how scarce resources are distributed in a process, and how scarce materials are apportioned to units. This analysis takes into consideration the accounting cost, economic cost, opportunity cost, and other costs of resources. Allocation of resources is a central theme in economics which is essentially a study of how resources are allocated and is associated with economic efficiency and maximization of utility. The allocation of the best type of manure to growing of crops is crucial to farmers and most crops in various environments depend on manures or technologically advanced specie of a crop to grow effectively well.

Soil nutrition is a major determinant in the level of crop growth and corresponding yield. To improve the nutrition level of the soil, several other studies have examined how organic manures and chemical fertilizers influence the growth of crop yields. The use of chemical fertilizers and organic manure has both positive and negative effects on plant growth and the soil. Chemical fertilizers are relatively inexpensive, have high nutrient contents, and are rapidly taken up by plants.

However, the use of excess fertilizer can result in a number of problems, such as nutrient loss, surface water and

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groundwater contamination, soil acidification or basification, reductions in useful microbial communities, and increased sensitivity to harmful insects (Chen 2006). Chand et al. (2006) have reported that the mixed use of nitrogen–phosphorus–potassium (NPK) chemical fertilizer and livestock organic manure increases the mean growth of mint and mustard by 46% and the soil concentrations of nitrogen, phosphorus, and potassium by 36%, 129%, and 65%, respectively.

Kaur et al. (2005) compared the use of chemical fertilizer treatment only and mixed chemical fertilizer and organic manure treatment in farmland rotating sorghum and wheat, and found that organic manure increased the soil concentrations of organic carbon, nitrogen, phosphorus, and potassium, thus highlighting its importance in tropical farmland, which lacks organic matter.

A study on tomatoes and corn in acidic soil by Murmu et al. (2013) found that organic manure increases crop productivity, nitrogen utilization efficiency, and soil health compared to chemical fertilizer.

II. RESEARCH METHODOLOGY

The data for this study was collected using a designed experiment on cassava variety cultivation at Precious Farms, Benin City. The data were based on observed growth of six cassava varieties planted after three weeks in same soil type in different plant verse. Each variety of crops is contained in all six forms of manure (organic and inorganic with a placebo). Each plant verse contains an adequately treated soil with a specific manure type.

Model Specification

The randomized complete block design was used in this study and this the model to be probabilistic rather than deterministic and such statistical model is applicable to the problem of making inferences about the population means and variance. Given a population of treatment (all the possible forms of soil manure), if interest is on determining whether the mean performance of all the treatments are same or not. We assume that the data are random samples collected from k normal population of the treatments.

The linear analysis model can be stated as:

$$y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \quad (1)$$

Where:

y_{ij} is the observation in the *i*th treatment and *j*th block

μ is the overall mean,

α_i is the *i*th treatment effect (type of manure)

β_j is the *j*th block effect (type crop)

ε_{ij} is the random error.

i is the treatment effect column

j is the block effect row

n is the total of observation

This model is completely additive.

Block Design Partitioning of Total Variability

SS_{TOTAL} this is the total sums of square that measures the total variability

$$SS_{TOTAL} = \sum_{i=1}^{n}\sum_{j=1}^{n}(y_{ij} - \bar{y}_{i.})^2 \quad (2)$$

$$SS_{TOTAL} = n^2\sum_{i=1}^{n}(\bar{y}_{i.} - \bar{y}_{..})^2 + n^2\sum_{j=1}^{n}(\bar{y}_{.j} - \bar{y}_{..})^2 + \sum_{i=1}^{n}\sum_{j=1}^{n}(y_{ij} - \bar{y}_{i.} - \bar{y}_{.j} + 2\bar{y}_{..})^2 \quad (3)$$

$$SS_{TOTAL} = \sum_{i=1}^{n}\sum_{j=1}^{n} y_{ij}^2 - \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{y_{ij}^2}{n^2} \quad (4)$$

SS_{Br} this is the sums of square due to block variability

$$SS_{Br} = n^2\sum_{i=1}^{n}(\bar{y}_{i.} - \bar{y}_{..})^2 = \sum_{i=1}^{n}\frac{Br_i^2}{t} - \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{y_{ij}^2}{n^2} \quad (5)$$

SS_{trt} this is the sums of square due to treatment variability

$$SS_{trt} = n^2\sum_{i=1}^{n}(\bar{y}_{.j} - \bar{y}_{..})^2 = \sum_{i=1}^{n}\frac{T_j^2}{b} - \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{y_{ij}^2}{n^2} \quad (6)$$

SS_{error} this is the sums of square due to random error variability

$$SS_{error} = SS_{TOTAL} - SS_{Br} - SS_{trt} \quad (7)$$

TABLE 1: ANOVA Table of Block Design (TWO-WAY)

Source of variation	**Degree of freedom**	**Sum of squares (SS)**	**Mean square (MS)**	F_{ratio}
Block	(b-1)	SS_{Br}	$MS_{Br} = \frac{SS_{Br}}{b-1}$	$F_{ratio} = MS_{Br}/MS_{error}$
Treatment	(t-1)	SS_{trt}	$MS_{trt} = \frac{SS_{trt}}{t-1}$	$F_{ratio} = \frac{MS_{Bc}}{MS_{error}}$
Error	(b-1) (t-1)	SS_{error}	$MS_{error} = \frac{SS_{error}}{(n-1)(n-2)}$	$F_{ratio} = \frac{MS_{trt}}{MS_{error}}$
Total	$bt-1$	SS_{TOTAL}		

Data Presentation and Analysis

TABLE 2: Growth (height) of cassava after 3 weeks of cultivation

CASSAVA SPECIES	**Poultry waste**	**Cattle dung**	**NPK fertilizer**	**Green manure**	**Palm waste**	**Placebo**
TMS 00/0203	26.2 cm	24.8 cm	25.9 cm	22.2 cm	24.1 cm	21.9 cm
TMS 01/0040	24.6 cm	25.1 cm	25.9 cm	20.6 cm	25.6 cm	21.7 cm
TMS 01/0040	26.8 cm	24.6 cm	25.2 cm	22.8 cm	25.8 cm	22.8 cm
TMS 00/0203	25.4 cm	26.4 cm	25.2 cm	21.4 cm	24.8 cm	21.6 cm
CR 41-10	26.4 cm	23.8 cm	25.1 cm	22.4 cm	25.4 cm	21.8 cm
NR 01/0004	25.3 cm	25.2 cm	25.1 cm	21.3 cm	24.9 cm	21.4 cm
Cost of applying manure in every 20ft×20ft	N80	N250	N380	N75	N95	0

TABLE 3: Two-Way ANOVA layout of the experimental result

	Treatment factors					
Blocking factors	τ_1	τ_2	τ_3	τ_4	τ_5	τ_6
β_1	26.2 cm	24.8 cm	25.9 cm	22.2 cm	24.1 cm	21.9 cm
β_2	24.6 cm	25.1 cm	25.9 cm	20.6 cm	25.6 cm	21.7 cm
β_3	26.8 cm	24.6 cm	25.2 cm	22.8 cm	25.8 cm	22.8 cm
β_4	25.4 cm	26.4 cm	25.2 cm	21.4 cm	24.8 cm	21.6 cm
β_5	26.4 cm	23.8 cm	25.1 cm	22.4 cm	25.4 cm	21.8 cm
β_6	25.3 cm	25.2 cm	25.1 cm	21.3 cm	24.9 cm	21.4 cm
C_{eu}	*N80*	*N250*	*N380*	*N75*	*N95*	0

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III. Results and Discussion

TABLE 4: RCBD ANOVA Result
Dependent Variable: Growth (height) of cassava (cm)

Sources of Variation	Sums of Squares	df	Mean Square	F	Sig.
Soil Nutrient Effects	99.851	5	19.970	39.719	.000
Cassava Species Effect	.723	3	.241	.479	.699
Error	13.575	27	.503[a]		
Total	114.149	35			

a. MS(Error)

From table 4 above, the result revealed that the soil nutrient effect is significantly different with variance ratio 39.719 and a corresponding $P = 0.000$. The effect of the cassava species on the growth of crops was highly insignificant with variance ratio 0.479 and $P > 0.05$. This result implies that the type of soil manure applied to growing crops; possess varying level of effect on the crop yields significantly. We generated a multiple comparison approach towards obtaining the most significant soil nutrient manure in improving cassava crop yield using the Tukey HSD method.

TABLE 5: Tukey HSD Significance Classification

Soil Manure type	N	Subset	
		1	2
Green manure	6	21.7833	
Placebo	6	21.8667	
Cattle dung	6		24.9833
Palm waste	6		25.1000
NPK fertilizer	6		25.4000
Poultry waste	6		25.7833
Sig.		1.000	.393

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .503.
a. Uses Harmonic Mean Sample Size = 6.000.
b. Alpha = 0.05.

The result in table 5 is a classification of treatment factors with significant difference into subsets. The Tukey HSD classification presented the mean effect in an ascending order of significance where the result indicated that treatment factor, green manure and the placebo effects have no resourceful effect in the improvement of cassava crop yield. However, with the classification on subset 2, the means appear higher than those in subset one, this implies that cattle dung, palm waste, NPK fertilizer and poultry waste possess possible crop yield improvement.

Table 6 examined the multiple pairwise comparisons to highlight the treatment effect with the highest significant level. The result contained in table 6 implies that the most effective manure in improving crop yield is the poultry waste. Next to it is NPK fertilizer, palm waste and cattle dung, which all proved significant in increasing the height of cassava (yield).

IV. Conclusion and Recommendation

This study evaluated a technique of optimizing the yield of cassava crop with various forms of manure using a randomized complete block design (RCBD). The result of the study have been able to show that soil nutrients can be optimized using RCBD model. The findings revealed that optimally, the poultry waste is best for improving soil nutrients for cultivating cassava. In the findings of this study, it was concluded that the RCBD model is efficient in optimization problems. Also, farmers should try the practice the use of poultry waste in growing their cassava crop instead of using inorganic fertilizers which cost more and also contains potential health effects.

TABLE 6: Tukey HSD Multiple Comparisons
Dependent Variable: Growth (height) of cassava (cm)

(I) Soil Manure type	(J) Soil Manure type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Cattle dung	Green manure	3.2000*	.40938	.000	1.9457	4.4543
	NPK fertilizer	-.4167	.40938	.908	-1.6710	.8376
	Palm waste	-.1167	.40938	1.000	-1.3710	1.1376
	Placebo	3.1167*	.40938	.000	1.8624	4.3710
	Poultry waste	-.8000	.40938	.393	-2.0543	.4543
Green manure	Cattle dung	-3.2000*	.40938	.000	-4.4543	-1.9457
	NPK fertilizer	-3.6167*	.40938	.000	-4.8710	-2.3624
	Palm waste	-3.3167*	.40938	.000	-4.5710	-2.0624
	Placebo	-.0833	.40938	1.000	-1.3376	1.1710
	Poultry waste	-4.0000*	.40938	.000	-5.2543	-2.7457
NPK fertilizer	Cattle dung	.4167	.40938	.908	-.8376	1.6710
	Green manure	3.6167*	.40938	.000	2.3624	4.8710
	Palm waste	.3000	.40938	.976	-.9543	1.5543
	Placebo	3.5333*	.40938	.000	2.2790	4.7876
	Poultry waste	-.3833	.40938	.933	-1.6376	.8710
Palm waste	Cattle dung	.1167	.40938	1.000	-1.1376	1.3710
	Green manure	3.3167*	.40938	.000	2.0624	4.5710
	NPK fertilizer	-.3000	.40938	.976	-1.5543	.9543
	Placebo	3.2333*	.40938	.000	1.9790	4.4876
	Poultry waste	-.6833	.40938	.563	-1.9376	.5710
Placebo	Cattle dung	-3.1167*	.40938	.000	-4.3710	-1.8624
	Green manure	.0833	.40938	1.000	-1.1710	1.3376
	NPK fertilizer	-3.5333*	.40938	.000	-4.7876	-2.2790
	Palm waste	-3.2333*	.40938	.000	-4.4876	-1.9790
	Poultry waste	-3.9167*	.40938	.000	-5.1710	-2.6624
Poultry waste	Cattle dung	.8000	.40938	.393	-.4543	2.0543
	Green manure	4.0000*	.40938	.000	2.7457	5.2543
	NPK fertilizer	.3833	.40938	.933	-.8710	1.6376
	Palm waste	.6833	.40938	.563	-.5710	1.9376
	Placebo	3.9167*	.40938	.000	2.6624	5.1710

Based on observed means.
The error term is Mean Square(Error) = .503.
*. The mean difference is significant at the 0.05 level.

References

[1] Bharathi, A. and Natarajan, A. M. (2010). Cancer Classification of Bioinformatics data using ANOVA. International Journal of Computer Theory and Engineering, 2(3):369-373

[2] Chand, S., Anwar, M., and Patra. D. D. (2006). Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint-mustard cropping sequence. *Commun Soil Sci Plant Anal*. 37(2):63–76.

[3] Chen, J. H. (2006). The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. Proceedings of International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use. Available from

http://www.agnet.org/htmlarea_file/library/201108081034/tb174.pdf

[4] Fraiman, D. and Fraiman, R. (2018). An ANOVA approach for statistical comparisons of brain networks. Scientific Reports (8)

[5] Hajihassani, U. I. (2013): Sudden death factors of banking efficiency. *Psychological science*, Vol. 20 Issues 3 pp: 421-432

[6] Kaur, K., Kapoor, K. K., and Gupta, A. P. (2005). Impact of organic manure with and without mineral fertilizers on soil chemical biological properties under tropical conditions. *J Plant Nutr Soil Sci.* 168(1):117–122.

[7] Murmu, K., Swain, D. K., and Ghosh, B. C. (2013). Comparative assessment of conventional and organic nutrient management on crop growth and yield and soil fertility in tomato-sweet corn production system. *Aust J Crop Sci.* 7(11):1617–1626.

[8] Rangriz, U., Makovski, T., Watson, L. M. and Koutstaal, W. (2012). Dissociated mechanisms of extracting perceptual information into visual working memory. *The Journal of neuroscience: the official journal of the Society for Neuroscience,* 5(5): 56-69