Adopting the Split-Split-Plot Design in Boosting Internally Generated Revenue from Waterleaf Cultivation in Cross River State, Nigeria

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ABSTRACT

This research work has carried out a split-split plot analysis of the effect of specie, fertilizer type and pesticide type on the weights of waterleaf shoots. The research work used data collected from a research farm (at No. 10 Access School Road, Atimbo, Calabar) that was set-up by the researchers strictly for this purpose. The data gave information on waterleaf species planted on the plots (Virginia, large-leaf, and Broad-leaf waterleaf), the types of fertilizers used (control, organic – cow dung, inorganic – NPK), and the pesticide types used (insect repellant, animal repellant, and microbicide). The review of literature showed an absence of a study which had considered the simultaneous impact of the adopted waterleaf species, fertilizer types, and pesticide types, on the weights of waterleaf shoots, as they either studied the impact of these factors on waterleaf growth independently, or viewed the growth of waterleaf in terms of height (not weight, being the case of this study); therefore, the study was significant on this premise. The ANOVA table in the study showed explicitly that the whole-plot (waterleaf species), sub-plot (fertilizer type), and sub-sub-plot (pesticide types) were not accurately chosen, as the sub-plot error was greater than the whole-plot error, with both being even greater than the sub-sub-plot error. This ultimately implied that there was far less homogeneity at the sub-plot level compared to the whole-plot and sub-sub-plot levels, hence suggesting that a proper reordering should have the whole-plot (waterleaf specie) as the preferred sub-plot, the sub-plot (fertilizer types) as the preferred whole-plot, while the sub-sub-plot (pesticide types) retains its status as the preferred sub-sub-plot, since it had the least F-ratio. Based on the research results, we have recommended that our findings be adopted by waterleaf farmers, since tendencies abound that this could better their understanding of waterleaf cultivation, and ultimately massively boost internally-generated revenue from waterleaf cultivation, as well.

Keyword: Split-Split Plot Analysis, Waterleaf Specie, Fertilizer Types, and Pesticide Types

INTRODUCTION

Background of the study

Techniques in design and analysis of experiment, as a branch of statistics, have found a vast range of application in real life problems [2; 12; 16]. Particularly, this is due to how efficient they are at making fast and reliable inferences about such real-life problems [8; 14]. Amongst the available types of experimental designs so far developed, the most frequently used types are the factorial and fractional designs [8; 9]. These two popular designs are used because they are simple and direct when used for collecting and analyzing data under a variety of circumstances [5; 8; 9]. Notwithstanding, in some experiments involving multi-factors, it may be difficult for an investigator to completely randomize the order of the experimental runs owing to some economic and practical reasons [2; 14; 16]; in the event of this, the need for an extension of the theories of the factorial and fractional factorial designs often arise [3; 4; 6]. Nonetheless, such an extension is possible only when the investigator imposes several restrictions on the structure of the factorial or fractional factorial design [3; 4; 6]. This action by the investigator gives data having more complex error structure than that of a completely randomized design [1; 4].

The split-plot design is an efficient and usually implemented design strategy developed from such extension of the factorial or fractional factorial design by the investigator [7; 10; 11]. More so, this design is one which has recently received scholarly research attention [11]. The utilization of the split-plot design is vast, as can be

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seen in different areas of life, ranging from biology to agriculture and engineering [11; 12; 16]. In all these areas, the split-plot design has been proven to be a very efficient design strategy for analyzing processes in which an investigator's overall interest is not only to unravel the interplay effects of factors [10; 11], but also to order the factors in relation to how to contribute to such processes [12; 16]. This technique of split-plot comes in handy when the process aims to order the contributions of two factors to the yield of a process [11; 13]. However, should the interest of an investigator shift to ordering the contributions of three (3) factors to the yield of a process, the technique of split-plot becomes inappropriate, ultimately birthing the idea of split-split-plot design [2; 16].

In this research, three (3) factors in a waterleaf planting process were investigated in relation to the weights of the waterleaf shoots. The task of the researcher, in this investigation, was reordering these factors with regards to their levels of non-homogeneity and contribution to the waterleaf planting process using the technique of split-split-plot design.

Statement of the problem

Cross River State, located in the South-South region of Nigeria, is a State which boasts of being the first capital of Nigeria, and a tourism destination within the country. Although, in early years of the State's recent history, it was known to be a civil service State, it has grown beyond this to becoming a State that is bubbling with industrial and tourism activities also. However, besides the evolution of industrial and tourism activities abides the ever-growing attention of most inhabitants of the State (especially inhabitants around the Northern parts) to agriculture, be it at subsistence, pseudo-subsistent, or large-scale commercial levels.

Specifically, with regards to crop cultivation in the State, cocoa, yams, potatoes, cassava, seem to be predominantly cultivated within the Northern parts of the State (due to their high demand across all parts of the State), whereas the cultivation of vegetables are mainly practiced within the Southern parts of the State (due to their usage in preparing major delicacies, peculiar to the terrane). The most common amongst such vegetables are pumpkin leaf, waterleaf, greens, etc., and these vegetables are becoming more expensive to due to an increase in demand that one can closely tie to the rise in population, and cross-cultural appreciation for south-south delicacies. Surprisingly, irrespective of the growing demand for these vegetables (especially waterleaf) their cultivation has seemingly stayed humble, as one can, at best, find pseudo-subsistent farms cultivating them in, and around, the terrane.

This event of apparent relegation of the potential of waterleaf cultivation begs the following as questions, (i) is there no financial potential in commercial cultivation of waterleaf? (ii) if there is, what limiting factors in its cultivation could farmers address to make for encouragement of its large-scale commercial cultivation, and long-run benefit to Cross River State's internally generated revenue (IGR)? Preliminary field inquiries to this study showed that a major problem experienced by both subsistent and small-scale commercial waterleaf farmers is their inability to precisely ascertain what factor amongst: waterleaf specie, fertilizer types, and pesticide types, contributes most significantly to the weights of waterleaf species after repeated planting seasons. In other words, such farmers lacked the ability to determine how these factors interplay, and should be ordered, to produce the best yield (weights of the waterleaf shoots).

Statistically, factorial and fractional design techniques cannot be used in tackling the problem that this circumstance encountered by such farmers presents, since the interests go beyond monitoring the interplay of factors to ordering them in relation to their relevance in the cultivation process. On the contrary, a suitable technique for analyzing this scenario is the split-split plot design, and the same was used in this study to address the identified problem.

Aim and objectives of the study

The study aimed to analyze the effect of waterleaf specie, fertilizer types, and pesticide types on the weights (yield) of waterleaf shoots. The specific objectives were to: (i) set-up a research waterleaf farm, (ii) organize replicates of requisite data (over the planting periods) from the research farm, and (iii) perform the split-split-plot design analyses on the organized data.

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MATERIALS AND METHODS

Research design

In research, a research design comprises the set of methods and procedures utilized in the collection and analyses of data (under specified variables) [15]. This research adopted an experimental research design – a type of research design that embodies all the processes of conducting research in an objective and controlled manner in order to guarantee maximum precision and draw specific conclusions about a hypothesis [15]. In this research, the split-split-plot experimental research design was used to obtain data from the plots of waterleaf.

Split-plot design

The split-plot design was developed by Sir Ronald Aylmer Fisher in 1925 for use in agricultural experiments [6; 9]. The split-plot designs are blocked experiments in which the blocks themselves serve as experimental units for a subset of the factors. In other words, there are two levels of experimental units [3; 4]. The blocks are referred to as whole-plots, while the experimental units within the blocks are called sub-plots (called split-plots or split-units). Corresponding to the two levels of experimental units, are two levels of randomization [3; 4]; the first randomization process is conducted to ascertain the assignment of block-level treatments to whole-plots, whereas the other randomization which assigns treatments to the split-plot experimental units occurs within each block or whole-plot [6; 9].

The split-plot design [9] is a generalization that results from the inability to completely randomize the order of the runs in some multifactor experiments. [13] defined the split-plot design as a special case of a factorial treatment structure which is used when some factors are harder (or more expensive) to vary than others; hence, it is one which consists of two (2) experiments with different experimental units of different size. This may explain one of the reasons why a split-plot design was described by [4] as a design which results from a two-stage randomization of a factorial treatment structure. Notwithstanding, [3] earlier described it as one in which the levels of one or more experimental factors are held constant for a batch of several consecutive experimental runs called a whole-plot. The linear model for the split-plot design with main treatment A and sub-treatment B is:

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \gamma_k + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \epsilon_{ijk} \qquad (1)$$

where: $i = 1,2,\ldots,r$, $j = 1,2,\ldots,a$ and $k = 1,2,\ldots,b$; τ_i, β_j; and $(\tau\beta)_{ij}$ represents the whole-plot, and corresponds, respectively, to replicates, main treatments (factor A), and WPE (replicates $\times A$); γ_k, $(\tau\gamma)_{ik}$, $(\beta\gamma)_{jk}$ and $(\tau\beta\gamma)_{ijk}$ represent the sub-plot and correspond, respectively, to the sub-plot treatment (factor B), the replicates $\times B$, the AB interactions, and the SPE (replicate $\times AB$). Note that WPE is the replicates $\times A$ interaction and the SPE is the three-factor interaction replicates $\times AB$. The sums of squares for these factors are computed as in the three-way analysis of variance without replication. The ANOVA for the split-plot design, with replicates, random and main treatments, and sub-plot treatments fixed, are shown in Table 1. Note that the main factor (A) in the whole-plot is tested against the WPE, whereas the sub-treatment (B) is tested against the replicates $\times$ sub-treatment interaction. The AB interaction is tested against the SPE. Notice that there are no tests for the replicate effect (A) or the replicate $\times$ sub-treatment (AC) interaction [6; 9].

Split-split-plot design

The split-split-plot design is especially suitable for three-factor experiments where different levels of precision are required for the factors evaluated [3; 4]. Split-split-plot design is characterized by: (i) three plot sizes corresponding to the three factors; namely, the largest plot for the main factor, the intermediate size plot for the sub-plot factor, and the smallest plot for the sub-sub-plot factor, and (ii) three levels of precision with the main plot factor receiving the lowest precision, and the sub-sub-plot factor receiving the highest precision [2; 9]. The analysis of variance table for the split-split-plot model is shown in Table 2. The statistical model for a split-split-plot design is given as:

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$$y_{ijkh} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \gamma_k + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \delta_h + (\tau\delta)_{ih} + (\beta\delta)_{jh} + (\tau\beta\delta)_{ijh} + (\gamma\delta)_{kh} + (\tau\gamma\delta)_{ikh} + (\beta\gamma\delta)_{jkh} + (\tau\beta\gamma\delta)_{ijkh} + \epsilon_{ijkh} \quad (2)$$

where, $i = 1,2,\ldots,r$, $j = 1,2,\ldots,a$, $k = 1,2,\ldots,b$, and $h = 1,2,\ldots,c$.

Study area

The research was performed at a research farm located at No. 10 Access School Road, Atimbo, Calabar. This farm was designed and constructed by the researchers specifically for the research, using the field reports on the weights of waterleaf species in plots prepared using waterleaf species (Virginia, large-leaf, and Broad-leaf waterleaf), types of fertilizers (control, organic – cow dung, inorganic – NPK), and pesticide types (insect repellant, animal repellant, and microbicide).

Data type

Both primary and secondary data were used in this research. The primary data were obtained from the report/log books on field experiments; such data were used for the split-split-plot analysis based on the objectives of the study. The summary of the report is put in the Appendix section of this article. The report showed the weights of waterleaf shoots after 4 repeated 5-week periods in plots varied with waterleaf specie, fertilizer types, and pesticide types. But the secondary data utilized in this research were obtained from articles published in reputable international journals, other online sources, and text books; the information were used for developing conceptual frameworks.

Table 1 ANOVA table for the split-plot design

Source of variation	DF	SS	MSS	F-ratio
Replicate	$r-1$	RSS	$\frac{RSS}{r-1}$	
Factor A	$a-1$	ASS	$\frac{ASS}{a-1}$	$\frac{AMS}{Error(a)MS}$
$Error(a)$	$(r-1)(a-1)$	$Error(a)SS$	$\frac{Error(a)SS}{(r-1)(a-1)}$	
Factor B	$(b-1)$	BSS	$\frac{BSS}{b-1}$	$\frac{BMS}{Error(b)MS}$
$A \times B$	$(a-1)(b-1)$	$(A \times B)SS$	$\frac{(A \times B)SS}{(a-1)(b-1)}$	$\frac{(A \times B)MS}{Error(a)MS}$
$Error(b)$	$a(r-1)(b-1)$	$Error(b)SS$	$\frac{Error(b)SS}{a(r-1)(b-1)}$	
Total	$rab-1$	TSS		

Table 2 ANOVA table for the split-split-plot design

Source of variation	DF	SS	MS	F-ratio
Replicate	$r-1$	RSS	$\frac{RSS}{r-1}$	
Factor A	$a-1$	ASS	$\frac{ASS}{a-1}$	$\frac{AMS}{Error(a)MS}$
$Error(a)$	$(r-1)(a-1)$	$Error(a)SS$	$\frac{Error(a)SS}{(r-1)(a-1)}$	
Factor B	$(b-1)$	BSS	$\frac{BSS}{b-1}$	$\frac{BMS}{Error(b)MS}$
$A \times B$	$(a-1)(b-1)$	$(A \times B)SS$	$\frac{(A \times B)SS}{(a-1)(b-1)}$	$\frac{(A \times B)MS}{Error(b)MS}$

$Error(b)$	$a(r-1)(b-1)$	$Error(b)SS$	$\frac{Error(b)SS}{a(r-1)(b-1)}$	
C	$(c-1)$	CSS	$\frac{CSS}{a-1}$	$\frac{CMS}{Error(c)MS}$
$A \times C$	$(a-1)(c-1)$	$(A \times C)SS$	$\frac{(A \times C)SS}{(a-1)(c-1)}$	$\frac{(A \times C)MS}{Error(c)MS}$
$B \times C$	$(b-1)(c-1)$	$(B \times C)SS$	$\frac{(B \times C)SS}{(b-1)(c-1)}$	$\frac{(B \times C)MS}{Error(c)MS}$
$A \times B \times C$	$(a-1)(b-1)(c-1)$	$(A \times B \times C)SS$	$\frac{(A \times B \times C)SS}{(a-1)(b-1)(c-1)}$	$\frac{(A \times B \times C)MS}{Error(c)MS}$
$Error\ (c)$	$(ab)(r-1)(c-1)$	$Error\ (c)SS$	$\frac{Error(c)SS}{(ab)(r-1)(c-1)}$	
Total	$rabc-1$	TSS		

Procedure for data randomization (collection) and analysis

The randomization procedure for the split-split-plot arrangement consists of three parts, namely:

i. Randomly assign whole-plot treatments to whole-plot based on the experimental design used.
ii. Randomly assign sub-plot treatments to the sub-plots.
iii. Randomly assign sub-sub-plot treatments to the sub-plots, noting that the experimental design utilized for randomizing the whole-plots will not affect randomizations of the sub-plot and sub-sub-plots.

Data from the report book (or log book) in the study area were organized and used for performing the split-split-plot analysis. The analysis was used to explain the effect of waterleaf specie (whole-plot), fertilizer types (sub-plot), and pesticide type (sub-sub-plot) on the weights of the waterleaf after 4 repeated (replicated) periods of 5 weeks.

Each factor was tested at three levels coded respectively by $(0, 1, 2)$. For waterleaf specie, we had Virginia specie as 0, large-leaved specie as 1, and broad-leaved specie as 2; for the fertilizer type, we had the control as 0, organic manure (cow dung) as 1, and inorganic manure (NPK) as 2; finally, for the pesticide types, we had insect repellant as 0, animal repellant as 1, and microbicide as 2. This amounted to a total of 27 sub-sub-plot combinations and 9 sub-plots of equal dimensions, and 3 whole plots, as shown in the farm's structural dimension and set-up in FIG. 1.

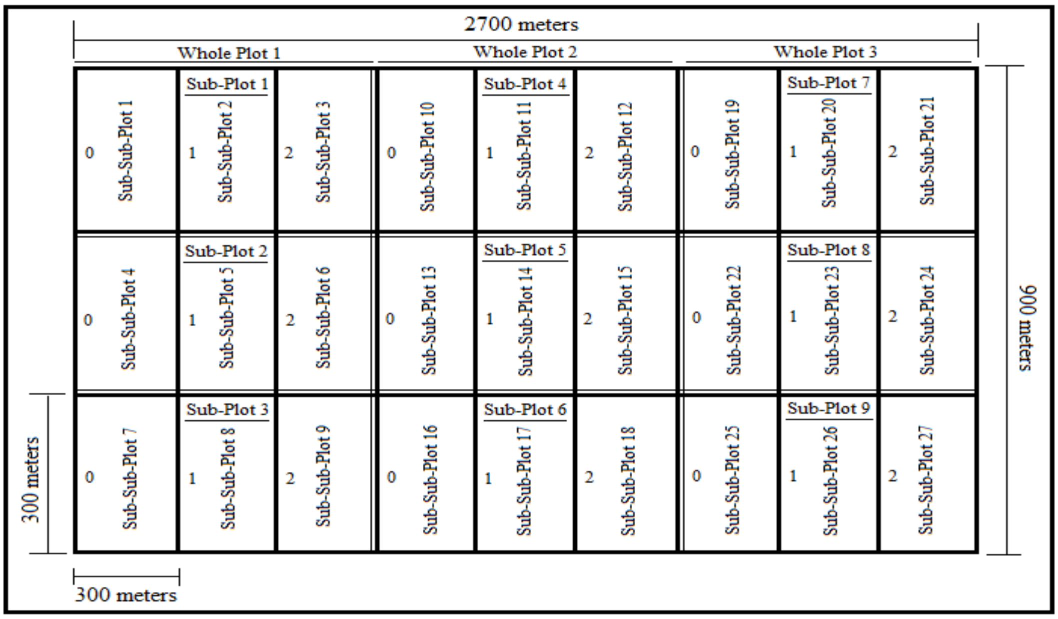

FIG. 1: Structural Dimension and Set-Up of the Research Farm

Current challenges to generating revenue from waterleaf cultivation in Cross River State, Nigeria

At the time of this research, the following challenges were identified as the current challenges to generating revenue from waterleaf cultivation in Cross River State, Nigeria.

i. An obvious disregard by farmers and government to the potential of waterleaf cultivation, hence the reason why there are more subsistent and pseudo-subsistent farmers in the State than there are commercial waterleaf farmers.
ii. A clear lack of proper structure for expanding waterleaf cultivation to full-blown commercial cultivation.
iii. A clear lack of proper structure for monitoring and regulating the proceeds currently generated from pseudo-subsistent waterleaf cultivation by means of tax.
iv. An apparent lack of understanding by waterleaf farmers on mechanized cultivation of waterleaf, as well as the combination of significant contributory factors to its growth.

RESULTS

The split-split-plot data collected over a 5-week study of waterleaf specie, fertilizer types, and pesticide types, with regards to the weights of waterleaf shoots, as seen in the Appendix section of this article, is summarized in Table 3 and Table 4, respectively, for the totals for two-way interaction, and totals for main effects. These tables are used to make the computations for each component of the ANOVA table in Table 5.

Table 3 Totals for Two-Way Interaction

	$S \times F(Y_{.jk.})$			$S \times P(Y_{.j.l})$			$F \times P(Y_{..kl})$			
	f_0	f_1	f_2	p_0	p_1	p_2		f_0	f_1	f_2
s_0	270.1	310.9	347.5	303.4	310.8	314.3	p_0	267.1	315.6	344.4
s_1	275.7	322.2	343.7	309.1	313.9	318.6	p_1	274.2	320.9	345.5
s_2	279.0	330.0	344.2	314.6	315.9	322.7	p_2	283.5	326.6	345.5

Table 4 Totals for Main Effects

$S(Y_{.j..})$			$F(Y_{..k.})$			$P(Y_{..l})$		
s_0	s_1	s_2	f_0	f_1	f_2	p_0	p_1	p_2
928.5	941.6	953.2	824.8	963.1	1035.4	927.1	940.6	955.6

Step 1: Calculate the correction factor

$$CF = \frac{Y_{\dots}^2}{rsfp} = \frac{(2823.3)^2}{4 \times 3 \times 3 \times 3} = 73{,}805.7675$$

Step 2: Calculate total sum of squares

$$TSS = \sum y_{ijkl}^2 - CF = (20.5^2 + 22.3^2 + 20.2^2 + \cdots + 28.8^2) - 73{,}805.7675 = 698.5625$$

Step 3: Calculate replicate sum of squares

$$RepSS = \frac{\sum y_{i\dots}^2}{sfp} - CF = \frac{(699.4^2 + 708.1^2 + 705.5^2 + 710.3^2)}{3 \times 3 \times 3} - CF = 2.466203704$$

Step 4: Calculate S sum of squares

$$S(SS) = \frac{\sum y_{.j.}^2}{rfp} - CF = \frac{(928.5)^2 + (941.6)^2 + (953.2)^2}{4 \times 3 \times 3} - CF = 8.48388889$$

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Step 5: Calculate whole-plot sum of squares

$$Whole\ plot\ SS = \frac{\sum y_{ij}^2}{fp} - CF = \frac{229.6^2 + 232.1^2 + 232.2^2 + \cdots + 238.7^2}{3 \times 3} - CF = 11.40472222$$

Step 6: Calculate $Error(s)$ sum of squares

$$Error(s)SS = Whole\ plot\ SS - S(SS) - RepSS = 11.40472222 - 8.48388889 - 2.466203704 = 0.454629626$$

Step 7: Calculate F sum of squares

$$F(SS) = \frac{\sum y_{..k.}^2}{rsp} - CF = \frac{824.8^2 + 963.1^2 + 1035.4^2}{4 \times 3 \times 3} - CF = 636.1716667$$

Step 8: Calculate $S \times F$ sum of squares

$$(S \times F)\ SS = \frac{\sum y_{.jk.}^2}{rp} - CF - S(SS) - F(SS) = \frac{(270.1^2 + 275.7^2 + 279.0^2 + \cdots + 347.5^2)}{4 \times 3} - CF - S(SS) - F(SS) = 10.97111108$$

Step 9: Calculate sub-plot sum of squares

$$Sub - plot\ SS = \frac{\sum y_{ijk}^2}{c} - CF = \frac{(67.5^2 + 66.7^2 + 66.8^2 + \cdots + 86.8^2)}{3} - CF = 663.5691667$$

Step 10: Calculate $Error(f)$ sum of squares

$$Error\ (f)SS = Subplot - (S \times F)SS - F(SS) - Error(s)SS - S(SS) - Rep\ SS = 663.5691667 - 10.97111108 - 636.1716667 - 0.454629626 - 8.48388889 - 2.46620 = 5.0216667$$

Step 11: Calculate P sum of squares

$$P(SS) = \frac{\sum y_{...l}^2}{rsf} - CF = \frac{(927.1)^2 + (940.6)^2 + (955.6)^2}{4 \times 3 \times 3} - CF = 11.29166667$$

Step 12: Calculate $S \times P$ sum of squares

$$(S \times P)\ SS = \frac{\sum y_{.j..}^2}{rf} - CF - S(SS) - P(SS) = \frac{(303.4^2 + 309.1^2 + 314.6^2 + \cdots + 322.7^2)}{4 \times 3} - CF - S(SS) - P(SS) = 0.78444444$$

Step 13: Calculate $F \times P$ sum of squares

$$(F \times P)\ SS = \frac{\sum y_{..kl}^2}{rf} - CF - F(SS) - P(SS) = \frac{(267.1^2 + 274.2^2 + 283.5^2 + \cdots + 345.5^2)}{4 \times 3} - CF - F(SS) - P(SS) = 5.093333297$$

Step 14: Calculate $S \times F \times P$ sum of squares

$$(S \times F \times P)\ SS = \frac{\sum y_{.jkl}^2}{r} - CF - S(SS) - F(SS) - P(SS) - (S \times F)SS - (S \times P)SS - (F \times P)SS$$
$$= \frac{(93.2^2 + 90.5^2 + 93.2^2 + \cdots + 114.4^2)}{4} - CF - S(SS) - F(SS) - P(SS) - (S \times F)SS - (S \times P)SS - (F \times P)SS = 1.868888923$$

Step 15: Calculate $Error\ (p)$ sum of squares

$$Error(p)\ SS = Total\ SS - (S \times F \times P)SS - (F \times P)SS - (S \times P)SS - P(SS) - Error\ (f)SS - (S \times F)SS - F(SS) - Error(s)SS - S(SS) - RepSS = 15.95533334$$

Step 16: Develop the ANOVA Table

Table 5 ANOVA table for the split-split-plot design

Source of variation	DF	SS	MS	F-ratio
Replicate	3	2.47	0.82	
Factor S	2	8.48	4.24	53.00
$Error(s)$	6	0.45	0.08	
Factor F	2	636.17	318.09	1178.11
$S \times F$	4	10.97	2.74	10.14
$Error(f)$	18	5.02	0.27	
P	2	11.29	5.65	18.83
$S \times P$	4	0.78	0.20	0.67
$F \times P$	4	5.09	1.27	4.23
$S \times F \times P$	8	1.87	0.23	0.77
$Error\ (p)$	54	15.96	0.30	
Total	107	698.55		

DISCUSSION

We note from the Table 5 above that the sub-plot error (1178.11) is greater than the whole-plot error (53.00). This meant that the sub-plots (fertilizer types) were less homogeneous compared to the whole-plot (waterleaf species). This implied that it will be preferable to assign the waterleaf species to the sub-plots, and the fertilizer types to the whole-plot. However, we got the sub-sub-plot error (18.83) as even lesser than the whole-plot error (53.00). This meant that the sub-sub-plots (being pesticide types) were more homogeneous compared to the whole-plot (waterleaf species). This implied that it will be preferable to maintain the pesticide types as the sub-sub-plots, while fertilizer types and waterleaf specie should respectively be reassigned to whole-plots and sub-plots.

CONCLUSION

In conclusion, this study showed that the whole-plot (waterleaf species), sub-plot (fertilizer type), and sub-sub-plot (pesticide type) were not are appropriately ordered for this research, which was to analyze the effect of such factors on the weights of waterleaf in relation to levels of homogeneity of the factors. The research results showed that the sub-plot should have been the whole-plot, the whole-plot should have been the sub-plot, whereas only the sub-sub-plot was to maintain its status. The research results also showed that the split-split plot research design was a suitable economical design for this study, rather than factorial designs which would have required more experimental runs than what was used.

RECOMMENDATIONS

Although this article has only but tackled a part of the fourth challenge earlier identified as a challenge in generating revenue from waterleaf cultivation in Cross River State, Nigeria, nevertheless we yet recommend the following to waterleaf farmers and government.

i. Farmers and government must to pay attention to the potential of waterleaf cultivation. Here, they could set-up and encourage research on the medicinal and ornamental benefits of waterleaf, ultimately encouraging its exportation, rather than seeing it only as an edible herb (vegetable) needed for preparing native delicacies only.
ii. Government must implement a good structure for expanding waterleaf cultivation to full-blown commercial cultivation.
iii. Government must implement a proper monitory and regulatory system for the proceeds generated from the current pseudo-subsistent waterleaf cultivation.
iv. The findings of this research should be adopted and utilized by farmers as a means to acquiring understanding of the combinations of significant contributory factors in waterleaf cultivation. Furthermore, we beckon on all the waterleaf farmers to explore mechanized farming of waterleaf to help speed up the cultivation process to meet growing demand, and also ensure availability of the product all year round.

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APPENDIX

	Treatments			Replicates				Treatments	
	S_j	F_k	P_l	1	2	3	4	Totals	
	0	0	0	20.5	22.3	20.2	23.4	86.4	
	0	0	1	23.4	21.7	22.5	22.9	90.5	
	0	0	2	23.6	22.7	24.1	22.8	93.2	
Sub-Plot Total	$Y_{i00}.$			67.5	66.7	66.8	69.1	270.1	$Y_{.00.}$
	0	1	0	25.3	25.7	25.6	24.8	101.4	
	0	1	1	25.4	26.1	26.4	25.9	103.8	
	0	1	2	26.3	26.8	25.9	26.7	105.7	
Sub-Plot Total	$Y_{i01.}$			77.0	78.6	77.9	77.4	310.9	$Y_{.01.}$
	0	2	0	28.3	28.9	29.0	29.4	115.6	
	0	2	1	28.6	29.1	29.3	29.5	116.5	
	0	2	2	28.2	28.8	29.2	29.2	115.4	
Sub-Plot Total	$Y_{i02.}$			85.1	86.8	87.5	88.1	347.5	$Y_{.02.}$
Whole-Plot Total	$Y_{i0..}$			229.6	232.1	232.2	234.6	928.5	$Y_{.0..}$
	1	0	0	21.3	22.8	22.5	23.0	89.6	
	1	0	1	22.5	23.6	22.4	22.8	91.3	
	1	0	2	23.8	23.7	23.4	23.9	94.8	
Sub-Plot Total	$Y_{i10.}$			67.6	70.1	68.3	69.7	275.7	$Y_{.10.}$
	1	1	0	26.3	26.5	26.4	27.0	106.2	
	1	1	1	26.9	27.2	27.0	26.8	107.9	
	1	1	2	27.1	27.2	26.9	26.9	108.1	
Sub-Plot Total	$Y_{i11.}$			80.3	80.9	80.3	80.7	322.2	$Y_{.11.}$
	1	2	0	27.9	28.2	28.7	28.5	113.3	
	1	2	1	28.1	28.3	29.2	29.1	114.7	
	1	2	2	29.1	28.7	28.9	29.0	115.7	
Sub-Plot Total	$Y_{i12.}$			85.1	85.2	86.8	86.6	343.7	$Y_{.12.}$
Whole-Plot Total	$Y_{i1..}$			233.0	236.2	235.4	237.0	941.6	$Y_{.1..}$

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	2	0	0	22.5	22.7	23.1	22.8	91.1	
	2	0	1	23.1	24.0	23.2	22.1	92.4	
	2	0	2	22.7	24.9	23.5	24.4	95.5	
Sub-Plot Total	$Y_{i20.}$			68.3	71.6	69.8	69.3	279.0	$Y_{.20.}$
	2	1	0	27.5	26.7	26.5	27.3	108.0	
	2	1	1	27.1	27.3	27.5	27.3	109.2	
	2	1	2	28.3	28.3	28.2	28.0	112.8	
Sub-Plot Total	$Y_{i21.}$			82.9	82.3	82.2	82.6	330.0	$Y_{.21.}$
	2	2	0	28.5	28.9	29.0	29.1	115.5	
	2	2	1	28.4	28.7	28.3	28.9	114.3	
	2	2	2	28.7	28.3	28.6	28.8	114.4	
Sub-Plot Total	$Y_{i22.}$			85.6	85.9	85.9	86.8	344.2	$Y_{.22.}$
Whole-Plot Total	$Y_{i2..}$			236.8	239.8	237.9	238.7	953.2	$Y_{.2..}$
Replicate Total	$Y_{i...}$			699.4	708.1	705.5	710.3	2823.3	$Y_{....}$