Experimental Design as a Tool for Innovative Agriculture

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Abstract This paper discusses experimental design as a tool for innovative agriculture with particular emphasis on Latin square design (LSD). The data was obtained from the Field Experimentation practical of the students of the crop department, Akperan Orshi College of Agriculture Yandev (AOCAY) for the year 2015 and 2016. Four deferent brands of nitrogenous fertilizers were used and their effects on the yield of maize crops (in kilogram per unit area) were determined. The results from ANOVA show that in both cases, there is deference between the fertilizer treatment at significant levels of 0.05 and 0.01. This shows that the yield produced by the maize crops depends on the type of nitrogenous fertilizer applied but not necessary on the type of soil used. Several recommendations were made. One of such is that farmers should apply deferent types of nitrogenous fertilizers on maize crop to enhance productivity.

1. Introduction

Due to the dwindling in oil economy, our country Nigeria has now placed much emphasis on innovations in Agricultural sector to replace the crude oil, improve the economy and feed the entire population. The operation consume what you produce as introduced by the federal Government of Nigeria has made it possible for the statisticians to use experimental design as a yard stick to innovative agriculture. Recall that the federal government had in 2013, as part of its efforts to grow the national local industry and attract investments into its downstream segments banned the importation of packaged sugar into the country as had earlier done for retail parks of vegetable oil, noodle, cement among other products [1].

Experimental design can be defined as all the necessary steps taken to ensure that proper data and information are obtained in other to have accurate analysis that will lead to valid inferences or conclusions [2].

According to Eguda [3], statistical design of experiment is a procedure of designing the experiment so that accurate data will be collected, which may be analyzed by statistical methods resulting in valid and objective concussions. Thus if an experiment is to be performed most efficiently, then a scientific approach to designing the experiment must be employed.

The three main principle of experiment design are replication, randomization and blocking. By replication we mean repetition of the main experiment. Randomization is the underlying principal that makes the use of statistical methods in experiment design realistic. It includes both the allocation of experimental material and the order in which the individual runs or trials of the experiment agree to be carried out one randomly determined. Blocking is a technique employed to increase accuracy in experiment design. It means grouping of the experimental methods into more homogeneous groups.

Relevance of Experimental Design to Innovative Agriculture

The design of an experiment need to be planned carefully in advanced. The uses are based on the classification of the various types of design [4].

- i. Completely randomization is used to eliminate various sources of errors, such as soil fertility, type of fertilizer used and so on. Fig (1).
- ii. Randomized block design is used when it is desired to control one source of error or variability: namely the deference in blocks. Fig (2).
- iii. Latin squares are used to control two sources of error or variability at the same time such as the deference in rows and difference in columns. For example errors in different rows and columns could be due to changes in soil fertility in different parts of land, in such case, it desired that each treatment occur once in each row and once in each column fig (3).
- iv. Graeco – Latin square are used to control three sources of error or variability fig (4). However the square needs to be orthogonal.

D	A	C	C
B	D	B	A
D	C	B	D
A	B	C	A

Figure 1: Complete Randomization

Blocks	Treatments			
I	C	B	A	D
II	A	B	D	C
III	B	C	D	A
IV	A	D	C	B

Figure 2: Randomized Block

	Factor 1			
	D	B	C	A
	B	D	A	C
Factor 2	C	A	D	B
	A	C	B	D

Figure 3: Latin Square

$B\gamma$	A_β	$D\sigma$	$C\alpha$
$A\sigma$	$B\alpha$	$C\gamma$	D_β
$D\alpha$	$C\sigma$	B_β	Ar
C_β	$D\gamma$	$A\alpha$	$B\sigma$

Figure 4: Graeco – Latin Square

According to Douglas [5], experimental Design is relevance in imploring agriculture in many ways:

1. It plays an important role in agricultural technology commercialization and product realization activities which consist of new product design and formulation, manufacturing process development and process improvement.
2. It is applied in a non manufacturing or non product – development setting such as marketing, service operation and general business operation.
3. A key technology for innovation. Both break-through innovation and incremental innovation activities can benefit from the effective use of design of experiment.
4. Used for developing scientific (empirical) models for the agricultural improvement.
5. Used to study the performance of agricultural processes and systems. There include operators, machines, methods, people and other resources that transforms some input (often a material) into an output that has one or more observable response variables.

Analysis of Variance (ANOVA)

This is a statistical technique that uses tests bases on variance ratios to determine whether or not significant deference exist among the means of several Populations or groups of observations [2]. It is an extension of t-test statistic used to determine whether or not two means differ to the case where there are three or more means.

It has a wide application in the biological, agricultural, social and physical sciences. Hence, its use to increase productivity yield in agriculture cannot be left out such as comparison of different levels of nitrogenous fertilizer in growth and yield of maize or guinea corn.

Latin Square Designs (LSD)

This design uses two blocking variables for grouping the non-homogenous experimental plots. It involves the arrangement of m-treatment in m-rows and m-columns such that each treatment appears once in row and each column [2].

Model

The statistical model for (mxm) Latin square design is

$Y_{ijk} = \mu + r_i + c_j + \square_k + \epsilon_{ijk}$ i, j, k= 1,2, . . ., m. Where m is the size of the square.

Y_{ijk}= observation of the Kth treatment in i^{th} row and j^{th} column.

μ= overall mean or universal constant.

r_i = effect of ith row, $c_{j=}$ effect of jth column , $\square_k$ = effect of kth treatment.

ϵ_{ijk} = random error component associated with Y_{ijk}.

The major feature of LSD is its capacity to simultaneously handle two known sources of variation among experimental units, treating the sources of variation as two independent blocking [3].

Application of Latin Squares Design to Agriculture

According to Lakis [6], LSD is applied in agronomic research. To plan experiment means to decide how to observe and measure in other to minimize randomized variations and stress the effects of factors analyzed. Namely, it is of importance to minimize experimental errors. Thus the experimental design is expected to meet some of the principles stated in order to minimize experimental errors.. To increase the reliability of conclusion, and solve some other experimental issues latin square design play an important role.

According to Basker and Reanganathan [7], LSD minimizes the error in determining the effect of parameters which allows simultaneous, systematic and efficient variation of all parameters than classical method. It is used in agricultural research to adjust for fertility deference in two physical directions.

According to James [8], LSD allow for two blocking factors in other words, these design are used to simultaneously control (or eliminate) two sources of resource variability. For instance if you had a plot of land, the fertility of this land might change in both directions, North-south and East-West due to soil or moisture gradient. So both rows and columns can be used as blocking factors.

Whenever, you have more than one blocking factor, a Latin square design will allow you to remove the variation of these two sources from error variation. Because of double grouping, the experimental error is small for LSD compared to that of complete Randomize Block Design (CRBD) and Randomize Block Design (RBD). Hence LSD is more efficient than CRBD and RBD. As in the case of RBD, in LSD the data with missing observations can be analyzed by using missing plot technique.

Methodology

The main source of data collected is from the field work practical results of the students of crop department of AOCAY. The data is collected to determine the effect of four different brands of nitrogenous fertilizers (A=27-13-13, B = 20-10-10, C = 15-15-15 and D = Urea) on the yield (in Kilograms) of maize crop for the year 2015 and 2016. Fertilizers in a Latin – Square arrangement are used in other to eliminate source of errors due to variability in soil fertility. The numbers indicate yields in Kilogram per Unit area.

An ANOVA is used to determine whether there is a difference between the fertilizers at significance levels of (a) 0.05 and (b) 0.01

Table 1: ANOVA table for Latin Square Design

S.V	d.f	SS	MS	F-ratio
Rows	m-1	SS_{row}	MS_{row}	$F=MS_{row}/MS_{error}$
Columns	m-1	SS_{col}	MS_{col}	$F=MS_{col}/MS_{error}$
Treatments	m-1	SS_{trt}	MS_{trt}	$F=MS_{trt}/MS_{error}$
Error	(m-1)(m-2)	SS_{error}	MS_{error}	-
Total	m^2 -1	SS_T	-	-

Where $SS_{T=} \sqrt{\sum_{Ijk} Y_{Ijk}^2 - \frac{Y^2}{M^2}}$, $SS_{rows} = \frac{\sum_{iyi}^2}{M} - \frac{Y^2}{M^{21}}$

$$SS_{error} = SS_T - SS_{rows} - SS_{cols} = SS_{trts}$$

$MS_{rows} = = \frac{SS_{rows}}{m-1}$; $MS_{cols} = \frac{SS_{cols}}{m-1}$

$MS_{trt} = \frac{SS_{trt}}{m-1}$; $MS_{error} = \frac{SS_{error}}{(m-1)(m-2)}$

Results

Table 2: Data collected for the year 2015

				Total
A16	C21	D20	B14	71
D20	B13	A15	C19	67
B12	A20	C22	D20	74
C18	D17	B14	A15	64
Total 66	71	71	68	276

Table 3: Total yield for each brand of fertilizer 2015

	A	B	C	D	
Total	66	53	80	77	276

Correlation factor $\frac{Y2...}{M^2} = \frac{(266)^2}{16} = 4,761$

$SS_T = 16^2 + 21^2 + \dots + 14^2 + 15^2 - 4,761 = 149.0$

$SS_{row} = \frac{(71)^2}{4} + \dots \frac{(64)^2}{4} - 4,761 = 14.5$

$SS_{col} = (71)^2 + \dots \frac{(68)^2}{4} - 4761 = 4.5$

$SS_{trt} = (66)^2 + \dots + \frac{(77)^2}{4} - 4761 = 112.5$

$SS_{error} = 149.0 - 14.5 - 4.5 - 112.5 = 17.5$

Table 4: ANOVA table for the year 2015

SV	d.f	SS	Ms	F-ratio
Row	3	14.5	4.83	1.65
Column	3	4.5	1.50	0.51
Treatment	3	112.5	37.50	12.84
Residual (error)	6	17.5	2.92	-
Total	15	149.0	-	-

Table 5: Data collected for the year 2016.

				Total
A17	C20	D23	B13	73
D21	B11	A13	C17	62
B14	A18	C21	D22	75
C20	D19	B11	A19	69
Total 72	68	68	71	279

Table 6: Total yield for each brand of fertilizer for 2016

	A	B	C	D	
Total	**67**	**49**	**78**	**85**	**279**

Table 7: ANOVA table for the year 2015

SV	d.f	SS	Ms	F-ratio
Row	3	24.69	8.23	2.84
Column	3	3.19	1.06	0.37
Treatment	3	184.69	61.56	21.23
Residual (error)	6	17.37	2.90	-
Total	**15**	**229.94**	**-**	**-**

Discussion of Results

Discussion for the year 2015

(a)   Since $F_{3,\,6,\,0.05} = 4.767 > F_{ratio} = 1.65$, we can accept

We can accept at 0.05 level the hypothesis that there are equal row means. It follows that at 0.05 level there is no difference in the fertility of the soil from one row to another.

Also the F value for column is less than 1. , we shall conclude that there is no difference in soil fertility in the columns.

Since F value for the treatment is 12.84>4.76, we conclude that there is a difference between the fertilizers.

(b)   Since $F_{3,\,6,\,0.01} = 9.78 > F_{ratio} = 1.65$, we accept the hypothesis that there is no difference in soil fertility in rows (or the columns) at 0.01 level.

However, we must still conclude that for the treatment there is difference between fertilizers at 0.01 level.

Discussion for the year 2016

(a)   Since $F_{3,\,6,\,0.05} = 4.76$, we can accept at 0.05 level the hypothesis that there are equal row means. It follows that at 0.05 level there is no difference in the fertility of the soil from one row to another.

Also, the F value for column is less than 1; we shall conclude that there is no difference in soil fertility in the column.

Since F value for treatment is 21.23>4.76, we conclude that there is a difference between the fertilizers.

(b)   Since $F_{3,\,6,\,0.01} = 9.78 > F_{-ratio} = 2.84$ we can accept the hypothesis that there is no difference in soil fertility in the rows (or columns) at 0.01 level. However, we must still conclude that for the treatment there is difference between the fertilizers at 0.01 level.

Conclusion

In the paper, the data is collected to determine the effect of four different brands of nitrogenous fertilizers on the yield (in kilogram per unit area) of maize crops for two year (2015 and 2016). An ANOVA is used to determine whether there is a difference between the fertilizers at significance level of 0.05 and 0.01. Fertilizers in a Latin square arrangement are used in order to eliminate sources of error due to variability in soil fertility. The result shows that at 0.05 and 0.01 significant levels there is no difference in soil fertility. However, there is a difference between the different brands of fertilizer treatment at 0.05 and 0.01 significant levels. This shows that the yield produced by the maize crops depends on the brand of fertilizer applied but not necessary on the type of soil used.

Recommendations

1.   For the treatment, $F_{tab} > F_{-ratio}$ at both 0.05 and 0.01 significant levels. If following that in order to produce high yield of maize, farmers should apply different brands of nitrogenous fertilizers since the yield does not necessary depends on the type of soil but on the type of fertilizer applied.

2.   Enlightenment campaign should be given to the local farmers on how to make use of experimental design techniques in other to produce high yield.

3.   Different brands of nitrogenous fertilizer should be produced by the companies and sold to the public to enable farmers have easy access to them.

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