Mathematical Theory and Modeling
ISSN 2224-5804 (Paper) ISSN 2225-0522 (Online)
Vol.4, No.8, 2014

Screening of New strains of sugarcane using Augmented Block Designs

Otulo Wandera Cyrilus [1] Ojung'a Okoth Samson[2] and Otumba Edgar Ouko[3]
[1]Rongo University College P.O Box 103-40405 Rongo,Kenya
[2]Ministry of Devolution and Planning P.O Box 115, Pap Onditi, Kisumu, Kenya
[3]School of Mathematics, Applied Statistics and Actuarial science Maseno University
P. O. Box 333-40105, Maseno, Kenya
mcojijosamsa@gmail.com

Abstract

Sugar production has over time experienced a number of challenges, that is, the choice of the variety to plant; soil nutrients variation and market competition amongst others have greatly affected sugar production. This study has effectively and efficiently employed the technique of experimental designs to ascertain family selection by comparing Augmented Block designs and Randomized Complete block designs. The augmented block design is widely used in breeding programs, particularly in screening and selection of large number of germplasm lines with non-replicated test treatments and replicated control treatments to estimate the experimental errors. The study establishes a relationship between augmented block designs in screening and completely randomized block design in screening new strains of Sugarcane. In the two designs analyzed, we consider 5 test treatments and 2 control treatments for augment design and the same number of treatments for Randomized Complete Block Design. In the event of screening new sugarcane varieties, attempts have been made to find the effectiveness of augmented block designs and completely randomized block designs in test families and control checks where the results reveal that Augmented Block Design is 11.86 times more efficient than a Randomised Block Design. In the conclusion of this study we have shown that Augmented Block Design is better suited when the plots are limited and Randomized Complete Block Design is better suited when treatments are many.

Keywords: Augmented Block Design, Balanced incomplete block design, Randomized complete Block Design, Latin Square, Unreduced BIB Design.

1. Introduction

Statistics is a science of extracting information from a complex and noisy data with uncertainty while applied statistical methods help in analyzing data to serve specific purpose in application. This study has effectively analyzed new sugarcane varieties using Augmented Block Design and Randomized Complete Block Design in test families and check controls by the strength of their effectiveness. Most of research investigation involving design of experiments helps make meaningful comparisons **[1]**. In plant variety selection programmes where comparisons is between newly introduced strains and the commercial controls, the vital designs used are augmented block designs, completely randomized block designs, reinforced balanced incomplete designs, Latin squares and Gaeco Latin squares.

In this study we have used augmented block designs and randomized complete block design to screen new sugarcane strains by concentrating on their effectiveness and efficiencies in tests verses control experiments as applied to plant breeding of the new cane varieties. Farmers have several alternatives of varieties for field trials. The tested entries are related to their pedigrees of yield for performance since families selection approach is preferred due to its objectivity and useful traits of low hereditary as opposed mass selection. The analysis of different designs used in screening the newly introduced varieties of sugarcane thus suitable for family selection with replications have their relative efficiencies discussed into details with particular emphasis laid to an augmented block designs and randomized complete block design.

2 Augmented Block Designs and Randomized Complete Block Designs

This study analyzes different designs seeking to give a statistical approach to farmers choice of varieties by

screening the newly introduced varieties of sugarcane to eliminate poor selection of varieties through augmented block design and randomized complete block design.

2.1 Basic Concepts and Notation

i. Design

In this study, we take the view common among statisticians that a design is an allocation Θ of a set v treatments to a set of Ω plots. The design may be thought of as a function *f* from Ω to Θ: - plot ω receives treatments, and if $f(\omega) = \lambda$ is partitioned into blocks then *f* is called a block design. A block is proper if all its blocks have the same size *k*. If $k = v$ then we have a complete block design, otherwise if $k < v$ it's an incomplete block design.

ii. Balanced incomplete block design

This is an arrangement of *v* treatment in *b* blocks such that any block has *k* treatments, any treatment occurs in *r* blocks and any pair of treatments occurring in blocks. The five parameters are not independent but satisfy these two relations;

$vr = bk$ and $\lambda (v - 1) = r(k-1)$.

A Balanced Incomplete Block Design is then written as (v, k, and b) with

$$b = \frac{v(v-1)\lambda}{k(k-1)}$$

And

$$r = \frac{\lambda (v-1)}{k-1}$$

With respect to this study, we define a design in general as an allocation of a set Θ of *v* treatments to a set Ω of *b* blocks thus the design may be thought of as a function of *f* from Ω on to Θ.

Plot ω receives a treatment if $f(\omega) = \lambda$ and is partitioned into blocks, then *f* is called a block design with the size *k* for blocks.

If $k = v$ then we have a balanced incomplete block design.

iii. **Randomization**

This is a method of dealing with nuisance factor by balancing the nuisance factor across the experiment. It is done using random device or pseudo-random device to choose which factor combination is allocated to each experimental unit. Like blocking, randomization is another technique of dealing with nuisance factors only that for randomization the factors are unknown and uncontrollable. Majumda [2] in his handbook of statistics stated that randomization balances out the impact of nuisance factors across the experiment.

iv. Replication

This is a convenient way of increasing the size of the experiment and precision it implies making more than one measurement at the same combination factor level. It is necessary to let all sources of random variables operate

independently on every occasion so that replication can count as proper [3]. According Rao [4] in his book stated that replication can be exploited to produce a pure error estimate of σ which is employed in this study.

v. Latin squares

A Latin square of order s is an arrangement of *s* symbols in an *s x s* array such that each symbol occurs once in each row and once in each column of the array i.e. for a 4x4 Latin square in symbols ABCD would be

ABCD	ABCD	ABCD
BADC	CDAB	DCBA
CDAB	DCBA	BADC
DCBA	BADC	CDAB

These 4x4 Latin squares are mutually orthogonal since they are pair-wise orthogonal. A complete set of *S-1* mutually orthogonal Latin squares exists for any $S = p^n$ where *p* is a prime number [5]. This study uses Latin square method of constructing an augmented block design with given parameters.

vi. Unreduced B.I.B design

According to Mike Jacroux [6] these designs are obtained by taking all combinations of the v treatments k at a time with parameters given by

$$(v; k; b) = {}^{v} c_k \qquad (2.1)$$

$$v = {}^{v-1} c_{kr} \qquad (2.2)$$

And

$$\lambda = {}^{v-2} c_{K\ \ 2} \qquad (2.3)$$

vii. Reinforced incomplete block design

According to Das [7], if a number of control treatment *p* is added in every block of existing incomplete block design with the resulting design having $p + v$ treatment distributed in *b* blocks each of size $k + p$, such that newly introduced *p* treatments are replicated *b* times and the original *v* treatments *r* times, this design is now called reinforced incomplete block design.

viii. Augmented block design

An augmented experimental design is any standard experimental design in standard treatments to which additional (new) treatments have been added. The additional treatments requires enlargement of the complete blocks and incomplete block row column designs. Augmented designs that eliminates heterogeneity in one directions are called augmented block designs [8].

ix. Randomized complete block design

This is the simplest type of layout where in this study treatments are allotted to the experimental unit at random. This design essentially removes variability between blocks from the experimental errors. This was shown by Rajender and Gupta [9] in their abstract of augmented design and randomised complete block design with a two way elimination of heterogeneity.

3 Model building

A statistical model is basically an assumption relating effects of different levels of factors involved in an experiment alongside one or more terms representing the error effects. To provide more insight understanding of

the design, this study develops a two factor experiment in screening various sugarcane varieties; we therefore use the analogy of any agricultural experiment and refer to two-way classification as treatments and blocks as proposed by Das and Gupta in 1992 under model of communication in statistics [7].

In this study, we consider *v* treatments and b blocks and one experimental value which are the yields of sugarcane per acre corresponding to each treatment (plots) and blocks (variety) for i^{th} treatment and j^{th} block denoted by X_{ij} as in the analysis of variance.

3.1 Analysis of Variance

The ANOVA is a powerful statistical tool for test of significance. Since t-distribution is not adequate, ANOVA which is based on f-distribution is employed with a basic purpose to test homogeneity of several means. ANOVA is mainly used to dealing with analysis of agronomical data where variation is inherent and may be caused by either chance causes or assignable cause.

3.2 Two Way Classification

The values of response in this classification are affected by two factors. In this study, we have the yield of sugarcane varying for different treatments coded from one up to five and two others are used as controls like rations as well as the differences in variety. Let us now suppose that n breeds of sugarcane are divided into h different plots with each plot containing *k* varieties, if we consider the effect of *k* treatments, that is, rations given at random to cane variation in each plot on the yield of sugarcane.

Let X_{ij}= (yield of sugarcane from plot with j^{th} variety on ration i) i=1, 2, 3.....k,j=1,2,3.....h

We let the yield of sugarcane to be expressed as variable value in *k X h* two way table as below.

Treatment (Rations)	**Varieties of Sugarcane 1 2....j....h**	**Raw Total**	**Raw Means**
1	$^{X}11\ ^{X}12\ \ ....X_{1j}....X_{1h}$	R_1	X1.
2	$^{X}21\ ^{X}22\ \ ....X_{2j}....X_{2h}$	R_2	X2.
.	. . ..	.	.
.	. . ..	.	.
.	. . ..	.	.
i	$X_{i1}\ X_{i2}....X_{ij}....X_{ih}$	^{R}i	Xi.
.	.....	.	.
.	.....	.	.
K	$X_{k1}\ X_{k2}....X_{kj}....X_{kh}$	R_k	Xk.
column total	$C_1\ C_2.....C_j....C_h$		
column means	$X_{:1}\ X_{:2}.....X_{:j}....X_{:h}$		$\bar{X}_{..}$

Table 1: ANOVA Table for General model

From the table 1 above

$Ri = \sum_{j=1}^{h} Xij$ as the sum of observations in the i[th] row.

i=1,2….k, $Ci = \sum_{i=1}^{k} Xij$ as the sum of observations in the j[th] column.

j=1,2,….h . $\bar{X_{i.}} = \frac{i}{h}\sum_{i=1}^{h} Xij = Ri/_{h}$ mean yield of the i[th] treatment

$\bar{X_{.j}} = \frac{i}{h}\sum_{j=1}^{k} Xij = Ci/_{h}$ mean yield of the i[th] sugarcane

$\bar{X_{..}}$=Overall mean

$\bar{X_{..}} = \frac{i}{hk}\sum_{i=1}^{k}\sum_{j=1}^{h} Xij \frac{G}{hk}$, $V = \frac{1}{h}\sum_{i=1}^{k} Xi. = \frac{1}{k}\sum_{j=1}^{h} X.j$

3.3 The Mathematical Model and its Assumptions

Since we had only one observation per cell the mathematical model for the means is

$$X_{ij} = \mu_{ij} + \varepsilon_{ij};\ i = 1;\ \ldots..k;\ j = 1;\ 2\ldots\ldots\ldots\ldots h \qquad (3.1)$$

Where X_{ij} is the yield from sugarcane of i[th] variety and the random variables having normal distribution with means μ_{ij} and common but unknown variance σ^2 i.e. N (μ_{ij},σ^2)

The various effects are assumed additive and becomes;

(a) The general mean effect $\sum_{i=1}^{k}\sum_{j=1}^{h} \frac{\mu ij}{n}$ (3.2)

(b) The effect $\propto_i$ due to the i[th] plot is given by $\propto_i = \mu_i = \mu$ assuming that

$$\sum_{i=1}^{k} \propto i = 0 \qquad (3.3)$$

(c) The effect β_j due to j[th] cane variety is given by $\beta_j = \mu_{j\cdot} \mu$, assuming

$$\sum_{j=1} \beta j = 0 \qquad (3.4)$$

(d) Interaction effect $(\alpha\beta)_{ij}$ when the i[th] plot and j[th] variety of cane occurs simultaneously is given by:

$$(\alpha\beta)_{ij} = \mu_{ij} - \mu_{i} - \mu_{j} + \mu \qquad (3.5)$$

Taking into account one observation per cell the assumptions that

$$\sum_{j=1}^{h} \beta j = 0, \sum_{i=1}^{k} \alpha_i = 0 \qquad (3.6)$$

and

$$\sum_{i=1}^{k}\sum_{j=1}^{h} \varepsilon_{ij}$$

Therefore the mathematical model for the effects used in this study is

$$X_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$$

3.4 Randomized Complete Block Design

This is the simplest type of layout in which treatment are allotted to the experimental unit at random. The design in this study has considered one observation per treatment in each block, the order in which treatments run in each block is done randomly. The model we assumed in this study for RCBD is of the form;

$$X_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \qquad (3.8)$$

with estimates

$$\hat{\mu} = \bar{X}_{..}, \hat{\alpha} = \bar{X}_{i.} - \bar{X}_{..}, \hat{\beta} = \bar{X}_{j.} - \bar{X}_{..},$$

These estimates of αi, and β_j help in minimizing error.

Since the study considers treatments and block effects as deviations from the overall mean so that $\sum_{i=1}^{k} \propto i = 0$ and
$\sum_{j=1}^{h} \beta j = 0$.

The means for the model then appears as in the following table; Treatment effects are relative

	Blocks					
Treatment	**1**	**2**	**3**	**....**	**B**	**Means**
1	μ 11	μ 12	μ 13	...	μ 1b	x1:
2	μ 21	μ 22	μ 23	...	μ 2b	x2:
. . .	. . .	. . .	. . .	. . .	. . .	. . .
t	μ t1	μ t2	μ t3	...	μ tb	xt:
Mean	x:1	x:2	x:3	...	x:b	x::

Table 2: The means for the model

Such that the null hypothesis

H_o^T : No treatment effects: $t_1 = t_2 = \ldots.t_b = 0$ or otherwise

H_o^B: No blocks effects: $b_1 = b_2 = \ldots\ldots b_b = 0$ or otherwise

(usually not of interest but assessed to determine if blocking was successful in reducing the variability in the experimental units)

variability in the experimental units)

Source of variation	**SS**	**df**	**MSS**	**F-Ration**
Treatment	SST	v-1	$S_1 = SST/(V-1)$	$s1/s3$
Due to blocks	SSB	(b-1)	$S_2 = SSB/b-11$	$s2/s3$
Due to Error	SSE	(v-1)(b-1)	$S_2 = \frac{SSE}{(v\ \ 1)(b\ \ 1)} = S_3$	
Total	TSS	(bv-1)		

Table 3: The ANOVA Table for RCBD

3.5 Augmented Block Design (ABD)

ABD is any experimental design in standard treatment to which additional (new) treatment have been added. Augmented block design were introduced by Federer in 1956 [11] as an alternative to the systematically arranged checks and new treatments. ABDs provides several advantages in screening new treatments such as Genotypes, Insecticides and Drugs.

We consider an experimental design where ω tests treatment are to be compared with μ control treatment using n experimental units arranged in r blocks such that j^{th} block is of size $k_j > \mu$, for augmented block design each of the control treatment is replicated b times and occurs once in every block, while test treatment occurs only once in one block. The analysis of variance generated from ABD with $v = \mu + \omega$ treatments comprising of ω tests and μ controls arranged in b blocks having k_1 plots in block 1, k_2 plots in block 2,....up to k_b plots in block b such that $k_1 + k_2 + \ldots\ldots + k_b = n$ will appear as in the table below;

Source of variation	**SS**	**Df**	**MSS**	**F-Ratio**
Blocks eliminating treatment	b-1	ASSB	M_SSB = S_1	S_1/S_4
Treatment eliminating blocks	v-1	ASST		
Among tests	w-1	SST	M_SST = S_2	S_2/S_4
Among control	u-1	SSC	M_SSC = S_3	S_3/S_4
Error	n-v-b+1	SSE	MSE = S_4	
Total	n-1	TSS		

Table 4: The ANOVA Table for Augmented Block Design with $v = \mu + \omega$

4 Discussions of Results

4.1 ABD and RCBD

The two block designs are similar in the sense that in Randomized block design the control treatments are added to the design containing the test treatments whereas in the Augmented block design the test treatments are added to a design containing the control treatments. The outcomes produced by the two methods were insignificantly different.

		Augmented Block Design Scenario		
Treatments	**RCBD**	**ABD N(0,1)**	**ABD N(0,5)**	**ABD N(0,25)**
Treatments1	86.22	80.32	80.71	80.45
Treatments2	57.34	62.77	59.56	62.46
Treatments3	49.32	51.82	49.74	51.46
Treatments4	98.03	99.77	97.63	100.81
Treatments5	31.17	30.37	28.96	25.63
N39	59.56	61.25	62.66	64.29
CO945	60.68	59.81	60.31	59.30

Table 5: Comparison of treatment means generated by both ABD and RCBD

RCBD design produced higher figures for treatment1 though it is still within the treatment standard deviation.

4.2 Conclusion and Recommendations

In agricultural experiments, setting a block will always have some degree of intra block variation. The major factors affecting the variation are the number of plots per block. The more the number of plots or experimental units in a block, the higher the degree of intra blocks variations and vice-versa. A randomized complete block design is discouraged by this study when evaluating large number of treatments instead augmented block designs are encouraged due to the capability of having few plots per block. The study has revealed that in any randomized complete block designs the number of plots in every block is dictated by the number of treatments being evaluated. In conclusion, the study has revealed that augmented block designs are more efficient than randomized complete block design for a finite error variance. In most cases under agricultural experiments, error variances are assumes to be finite as it has been shown in the study.

Finally, we say that augmented block designs are more efficient than randomized complete block design in test treatments versus control treatment experiments hence more valuable in screening new stains of sugarcane. The efficiency of augmented block design when it is tailored to fit strongly in large inter block variation and scarce test treatment. This study recommends the use of augmented block design in screening new strains of sugarcane due to it's high efficiency as opposed to the randomized complete block designs which only appear to be simple.

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