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Comparative Efficiency of Randomized Complete Block Design Vs. Latin Square Design in Wheat Yield Trial

Syed Asghar Ali Shah[1] Alamgir[2] Murtaza Khan[1]
1.Agricultural Research Institute Tarnab, Peshawar, Pakistan
2.Department of Statistics, University of Peshawar, Pakistan

Abstract
The use of proper design in agricultural experimentation is very important for getting precise results. The comparative study of two major designs i.e. Randomized Complete Block Design (R.C.B.D) and Latin Square Design (L.S.D) was conducted through field experiment. The experiment was carried out with wheat variety Pirsabak-2004 during 2013/14 at Agricultural Research Institute Tarnab, Peshawar, Pakistan. The area allocated for RCB design was 0.247 hectare and area for LS design was allocated to be 0.08 hectare. The accuracy of crop designs was examined by judging the degree of variances in error of both designs and by comparing the efficiency of the experiments including the effect of degree of freedom. The relative efficiencies of RCBD and LSD were calculated to be 1.002 and 0.60 respectively. Therefore, based on the present findings it can be concluded that RCB design is appropriate for the experimental designing relative to LS design.
Keywords: Experiment design; Relative efficiency, Randomized Complete Blocks Design, Latin Square Design, Analysis of Variance.

INTRODUCTION
The good experimentation requires accurate planning, good Agricultural practices, data analysis and interpretation. In agricultural field experimentation use of proper design play an important role in attaining precision of results. The experiment is carried out by taking into account the Randomized Complete Block Design and Latin Square Design are briefly described as follows.

1.1) Randomized Complete Block Design (RCBD)
In Randomized complete block design (RCBD) each block size contains complete set of treatments and should be homogenous such that it results in the reduction of the experimental error. Randomized complete block designs differs from complete randomized designs by controlling only one source of variation i.e. experimental units are grouped into blocks by incorporating homogeneity characteristics. Variations (i.e. fertility, soil, irrigation and wind gradients) can be configured by suitable blocking. Therefore, it is important to consider that variations within each block is minimum and between block is maximum. The treatments are consigned to each block completely at random with a separate randomization for each block.
The model for RCBD or RBD is presented in Equation-1.1;

$$Y_{ij} = \mu + \beta_i + \tau_j + \varepsilon_{ij} \quad \text{----------------------------} \quad (1.1)$$

$\mu =$ overall true mean effect
$\beta_i =$ effect of i^{th} block
$\tau_j =$ effect of j^{th} treatment
$Y_{ij} =$ yield subjected to i^{th} block and j^{th} treatment
$\varepsilon_{ij} =$ random error or residual

1.2) Latin Square Design (L.S.D.)
The Latin square design differs from Randomized Block Design in the way that treatments are organized in complete group by controlling two sources of variations. Also, the two way classifications being orthogonal to the treatments and to each other. Where each row and column contains a complete set of treatments. Moreover, Latin Square Design differs from randomized complete block designs in the sense that the experimental units are arranged in blocks by two incorporating two sources of variations i.e. by using rows and columns.
The model for Latin Square design can be represented in Equation-1.2

$$Y_{ij\,(k)} = \mu + \beta_i + \gamma_j + \tau_k + \varepsilon_{ij} \quad \text{-----------------------------} \quad (1.2)$$

$\mu =$ mean effect
$\beta_i =$ i^{th} block effect
$\gamma_j =$ j^{th} column effect
$\tau_k =$ k^{th} treatment effect
$\varepsilon_{ij} =$ random error

Each treatment occurs once in each block and once in each column and No. of treatments, rows and columns must be equal say (P).

The main objective of the study is to compare two experimental designs employed in the field i.e. Randomized complete Block design (R.C.B.D) and Latin square design (L.S.D). The relative efficiency of one design to another is generally measured in relation to reduced error, expected error mean squares, or standard error of the difference between genotype means (Cochran and Cox, 1957, Binns 1987 and Magnussen 1990). The randomized block, latin square, and complete block sort of trials are useless to compare large quantity of treatments, due to failure of reducing the factor of soil heterogeneity (Lentner and Bishop 1993). It is recommended that Randomized complete block design (RCBD) is reasonable when the size of block is fewer than eight varieties per treatments and when the number of varieties per treatment increases i.e. more than ten, then there is an option of another design named alpha lattice design. The experimental error is inflated in case of large number of treatment therein and resulted in low precision. Therefore RCBD is inappropriate when there is 102 numbers of varieties is large as sixteen in a particular block (Yang *et al* 2004). In field experiments, difference in soil fertility can result in significant heterogeneity within blocks and resulted poor accuracy in estimating treatment can occur (Idrees and Khan 2009). Fisher (1926) stated in his first paper which were about field experimental designs in which he highlighted the importance of randomized arrangements in the estimation of experimental error and described the randomized complete block (RCB) and Latin square designs. However, in some situations, the proficiency of the RCB design is not so good. The homogeneity of experimental plot within the large block is problematic to sustain as the number of treatment increases with the complete blocking experiments and thus local control of experimental variability suits unfavorable (Stroup *et al* 1994).The use of common method in practice that is local control by means of replications is inept and a lot of research has freshly been carried out, which recommend new approaches of local control in field experimentation (Williams 1986, Cullis and Gleeson 1991, Kempton *et al* 1994, Gleeson 1997 and Malhotra *et al* 2004).

Materials and Methods

The experiment was carried out with wheat variety Pirsabak-2004 during Rabi-2013/14 at Agricultural Research Institute Tarnab, Peshawar, Pakistan. The area allocated for Randomized Complete Block Design and Latin Square Design was 0.247 hectare and 0.08 hectare respectively. The experiment is undertaken by applying seven selective fertilizer doses to randomized block experiment including one control which formed eight numbers of treatments in total and having four numbers of replications. The plot dimensions was 1.83 x 7.32 meter.

Relative Efficiency

In order to find the efficiency in agricultural experimentation R.A Fisher (1926) developed a formula that enables us to make comparison of the efficiency of two experiments and also to take into account the effect of degree of freedom we have

$$\frac{(n_2+1)(n_1-3)\varepsilon_1}{(n_1+1)(n_2-3)\varepsilon_2}$$

Where "ε_1" and "ε_2" are error mean square and "n_1" and "n_2" are degree of freedom for two experiments which is an expression for relative efficiency of the second experiment as compared to the first. The data of both designs were analyzed in statistical package Statistix-8.1 version.

RESULTS AND DISCUSSION:

1. **Analysis of Randomized Complete Block Design:**

The data was collected from each plot of Randomized Complete Block Design and yield in Kg/plot was recorded as shown in Table-1.1.

Table – 1.1. Yield Data of Wheat in kg/plot for RCBD

Treatments		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Block Total**
Blocks	1.	2.67	3.32	4.37	2.89	2.78	4.31	3.12	3.46	26.92
	2.	3.52	4.00	3.15	3.97	2.55	2.70	4.82	3.18	27.89
	3.	2.10	2.89	3.77	2.89	2.64	2.72	3.43	4.23	24.67
	4.	2.61	2.70	2.16	3.01	4.17	2.04	3.41	2.98	23.08
Treatment Total		10.90	12.91	13.45	12.76	12.14	11.77	14.78	13.85	102.56

The Analysis of variance for Randomized Complete Block Design is presented in Table-1.2 is described as under;

TABLE – 1.2:-Analysis of Variance for RCBD

Source of variation	DF	SS	MS	Observed F-Value.	Tabular	
					5%	1%
Blocks	3	1.78	0.59	1.13-ns-	3.07	4.87
Treatments	7	2.65	0.38	0.73-ns-	2.49	3.65
Error	21	10.93	0.52	--	--	--
Total	31	15.36				

-ns- Not significant at both levels

From Table-1.2 it is obvious that the tabular F-Value having 7 and 21 degrees of freedom at 5% and 1% levels of significance are 2.49 and 3.65 respectively. Since the observed F value is smaller than the tabulated F-value at 5% and 1% level of significance. Therefore it can be conclude that the experiment failed to show any significant differences among the eight treatments.

Likewise, the differences among blocks were also been computed by dividing the block mean square to the error mean square to obtain the observed F-value.

From Table-1.2, it is obvious that block performance was found to be non effective in reducing the size of the experiment error.

Relative efficiency = 1.012

This decrease is slightly due to the fact of completely randomized experiment. There are 24 degrees of freedom as compared to 21 for randomized blocks experiment. But this effect is small and can estimate this effect as;

$$\frac{(21+1)\,(24+3)}{(24+1)\,(21+3)} = .99$$

The corrected R.E = 1.00

2. Analysis of Latin Square Design:

The data was collected from each plot of Latin Square Design and yield in Kg/plot was recorded as shown in Table-1.3.

Table-1.3. Yield Data of Wheat Crop in Kg/Plot for LSD

	COLUMNS								Row Total	Treatment Total	Treatment Mean kg/plot.
Rows	2.72	3.46	3.43	3.18	2.55	2.07	2.36	1.87	21.64	18.67	2.33
	2.81	2.1	3.46	3.21	3.15	2.33	2.55	2.44	22.05	20	2.5
	2.27	2.3	3.26	3.38	2.55	2.87	2.55	2.84	22.02	21.08	2.64
	2.89	2.07	2.75	2.07	2.41	3.15	2.1	3.12	20.47	22.26	2.78
	2.27	2.95	3.94	3.29	2.13	2.5	2.24	2.41	21.73	22,81	2.85
	3.83	3.58	2.89	3.32	2.61	2.07	3.01	2.36	23.67	23.61	2.95
	3.52	3.12	3.35	3.12	2.21	2.33	1.62	3.09	22.36	23.58	2.95
	3.6	3.12	3.04	3.06	2.95	2.47	2.04	2.7	22.98	24.91	3.11
Total:	23.91	22.7	26.12	24.63	20.6	19.79	18.38	20.8	176.92	176.92	-----

The collected data is analyzed and ANOVA table for the said design is presented in Table-1.4.

TABLE – 1.4:- ANOVA for Latin Square Design

Source of variation	Degrees of Freedom	Sum of Squares	Mean Squares	Observed F-value	Tabular F-value	
					5%	1%
Rows	7	6.17	0.88	5.18 **	2.24	3.10
Columns	7	0.79	0.11	0.65 *ns-	2.24	3.10
Treatments	7	3.77	0.54	3.18**	2.24	3.10
Error	42	7.01	0.17	..	..	..
Total	63	17.74	..	..	..	..

** **Significant at both levels.**

From the Table-1.4, it is obvious that Columns mean squares are not significant. This is probably due to the shape of the plots having long and narrow. It is further added that the columns are narrow strips running along the length of the rectangular area. Under these settings, square may have little advantage on the average over a randomized block design.

As the columns contributes less as compared to rows, for reducing the amount of error. Moreover, the efficiency of experiment can be computed by applying the formula given by Cochran and Cox (1957), to estimate the error mean square if there is randomized block experiment with the rows as replicates.

$$E = \frac{7 \text{ x } 0.11 + 49 \text{ x } 0.17}{63} = 0.1018$$

Relative efficiency = .5988

Also, the effect of reduction in degrees of freedom is

$$\frac{(42+1)\,(49+3)}{(49+1)\,(42+3)}$$

The corrected R.E = 0.60

Conclusions and Recommendations:

The instant result suggests that the relative efficiencies in case of Randomized Complete Block design were found close to one as compared to Latin Square Design. Hence, it can be recommended that Randomized complete block design was found suitable for experimentation and should be preferred over Latin square design specifically in wheat variety pirsabak-2004 and wheat experimentation in general.

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