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Improvement in Precision of Agricultural field Experiments through Design and analysis

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Abstract

The efficiency of Alpha Lattice Design and Randomized Complete Block Design (RCBD) was compared in two research trials conducted at National Agricultural Research Centre (NARC), Islamabad, Pakistan on two different crops to assess the efficiency of each in minimizing experimental error, coefficient of variation and error mean square for yield variable. Alpha designs are used for field trials because they provide better control on experimental variability among the experimental units under field conditions. For this purpose, two research trials on wheat and potato crops using alpha lattice design were conducted at NARC, Islamabad. The results show improvements in the precision level (in terms of decline in the mean square error, coefficient of variation and standard error of difference). The coefficient of variation (CV) calculated for wheat and potato preliminary yield trials are (7.70 and 13.6) for alpha lattice design and (8.54 and 16.39) for RCBD respectively. The error mean squares (EMS) calculated for these trials are (0.95 and 2.07) for alpha lattice design and (1.18 & 3.01) for randomized complete block design (RCBD) respectively. Standard error of difference for alpha lattice design are (218 & 0.8312) and (343&1.41) for RCBD. The relative efficiency of trials shows that alpha lattice design was more efficient than RCBD. The value of relative efficiency (1.24 and 1.46) indicates that the use of alpha lattice design instead of randomized complete block design (RCBD) increased experimental precision by 24 and 46 percent respectively (table 1). The gain is considerable in terms of efficiency attained by using Alpha Lattice Design which favours wider use of these designs under field conditions.

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Introduction

The randomized block, Latin square, and other complete block types of experiments are inefficient for large number of treatments, because of their failure to adequately minimize the effect of soil heterogeneity. Generally, the greater the heterogeneity within blocks, the poorer the precision of variety effect estimates. Incomplete block designs are arranged in relatively small blocks that contain fewer varieties than the total number of varieties to be compared. Consequently, there is a gain in precision due to use of small blocks. As far as the layout of the experiment is concerned the incomplete block designs are no more difficult than randomized blocks. Some extra planning is involved in drawing up and randomizing the experimental plan. Randomized Complete Block Design (RCBD) is affordable when the block size is less than eight varieties/treatments. It is always useful to use incomplete block design when the number of varieties/treatments increases. Because of large number of treatments, the homogeneity among experimental units/plots within a large block cannot be maintained. As a result, estimate of experimental error is inflated and results are low in precision.

The usual approach through local control by blocking is inefficient and a lot of research has recently been carried out which suggest new methods of local control in field experiments (Gleeson and Cullis (1987), Cullis and Gleeson (1991), Kempton et.al (1994). Alpha designs introduced by Patterson and Williams, 1976 are now routinely used for statutory field trials in the United Kingdom (Patterson and Silvey, 1980) and are also widely used for breeding and varietals trials in Australia and elsewhere. They are more flexible than lattice designs and can accommodate any number of varieties. A computer programme ALPHA$^+$ (Williams and Talbot, 1993) is available for constructing efficient designs. Additional

improvement is possible through modelling field variability using spatial features of the field layout. It has been advocated by Wu and Dutilleul (1999) use of incomplete blocking is generally more effective in reducing the unexplained structured variation in comparison with complete blocking. Campbell and Bauer (2007) recommended researchers conducting cotton performance trials on variable soils consider using NNA or other spatial methods to improve trial precision.

The advantage of alpha designs is that they are easy to construct, and can be constructed in cases where balanced incomplete block designs and lattice designs don't exist. The early alpha designs were aimed primarily at controlling variation down the columns of plots in the field. This is often adequate when plots are long and narrow. Patterson and Hunter (1983) have demonstrated the value of alpha designs in such circumstances in terms of gain in efficiency.

Materials and Methods

The yield data come from preliminary wheat and potato yield trials, these were conducted by National Coordinated wheat and Potato Programs, NARC using alpha lattice design layout at National Agricultural Research centre, Islamabad in collaboration with Biometrics Program, NARC Centre (NARC), Islamabad, 2007-08. The experiment on wheat crop was laid out with 2 replications, 50 entries, 10 blocks consisting of five entries in each block, where as the experiment on potato crop was laid out with 3 replications, 25 entries, 5 blocks and 5 plots per block. The potato yield trial was planted on 2nd October 2007 and harvesting was done on 5th January 2008. The net plot size of experiment for each entry/variety in each replication was 15 m^2 (4 rows 5 meters long with spacing of 0.75m) and harvested area 9 m^2. Computer software named ALPHA, developed by CIMMYT was used for statistical analysis of alpha lattice design as well as Randomised Complete Block Deign.

The mean square error from each analysis was used to estimate the relative efficiency of an alpha lattice design compared with a RCBD according to the following equation:

$$\text{Relative Efficiency} = \frac{\text{Mean Square Error in RCBD}}{\text{Mean Square Error in Alpha Lattice Design}} \times 100$$

An estimated relative efficiency (ERE) less than 1 indicates that a RCBD is a more efficient design, while value nearly equal to 1 suggests that the two designs yield similar results. Value greater than 1 suggests that Alpha lattice design is more efficient design than RCBD. In this study, the efficiency of Alpha Lattice Design and Randomized Complete Block Design (RCBD) was compared in this research trials conducted in National Agricultural Research Centre (NARC), Islamabad, Pakistan to assess the efficiency of each in minimizing experimental error, coefficient of variation and error mean square for yield.

Results and Discussion

The results of the experiments show that there is large difference between error mean squares (EMS) under alpha design and RCB design. The coefficient of variation (CV) of alpha lattice design is comparatively low as compared to RCBD. Low value of CV indicates good index of reliability. The relative efficiency indicates how much more efficient the alpha lattice design is as compared to RCBD, if the value of relative efficiency is greater than one then the alpha lattice results in a smaller error variance and it adjusts genotype means for block effects. In addition to that the relative efficiency is less than one, the alpha lattice design is less efficient than the RCBD. In this case, the trail is analysed as a RCBD and means are not adjusted for block effects. There is big difference between standard error of difference under RCBD and average standard error of difference under alpha design. The smaller values of S.E. difference for alpha lattice design helps to detect smaller differences for the comparisons of mean.

Masood et.al (2006 & 2008) compared efficiency of alpha lattice design. The results indicated that alpha lattice design improved the efficiency 8-9 and 14 percent as compared to RCBD in these studies. YAU, (1997) reported the use of alpha lattice design in international yield trials of different crops and found average efficiency 18 % higher than the RCBD. The value of relative efficiency greater than one for both the experiments show that Alpha lattice design was clearly more efficient than RCBD (table1). Relative efficiency indicates that the use of alpha lattice design instead of RCBD increased experimental precision by 24 and 46 percent in wheat and potato respectively.

Conclusions

The results of this study show that Alpha lattice Design provided smaller standard errors of differences, coefficients of variation and error mean squares as compared to RCBD providing efficiency in comparing different entries/lines. Therefore this design should be employed while conducting field research trials on different crops in Pakistan when number of varieties in the experiments is large. There is also need to extend experimentation to more research stations for wider applicability of these designs for these crops and for some other crops too. For plant breeding and selection trials alpha lattice design should be used in such a way that they form a resolvable incomplete block design so that the results could be

analyzed through RCBD for comparison to check the required gains in efficiency.

Table.1. Results of Preliminary Yield Trials, NARC

Exp.	Mean square error		C.V		S.E. (diff)		R.E
	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD	
Year 2006-07							
Wheat	95390	117841	7.70	8.54	218	343	1.24
Year 2007-08							
Potato	2.072	3.016	13.6	16.39	0.831	1.418	1.46

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