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DESIGN IMPROVEMENT USING UNIFORMITY TRIALS EXPERIMENTAL DATA

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The design of field trials sometimes raises queries about alternative designs and the best ways that allowing for environmental variation in the area allotted to the experiment. In field trials, variation in soil fertility can result in substantial heterogeneity within blocks and thus, poor precision in treatment estimates resulted. In this study different complete and incomplete block designs (generalize lattice design) were superimposed with dummy treatment structure on uniformity trials data, so that efficient designing can be made. For all three sites under study, generalize lattice design was on the average more efficient than complete block analysis in reducing the error mean square. Maximum average efficiencies obtained were 2.23 at NARC, 3.64 at BARI and 2.33 at AARI.
Keywords: Environmental variation, soil fertility, generalized lattice designs, uniformity trials, average efficiency, error men square

INTRODUCTION

The agricultural sector is the single largest sector of Pakistan, contributing 25% of the gross domestic product (GDP) and providing employment to over 44% of the workforce. So the agricultural field experiments become an important part of research for new innovations in variety development and technology. The primary aim of most agricultural field experiments is the efficient estimation of treatment contrasts. To achieve this aim, it is important to control field variation that is due to causes such as experimental management, fertility trends, and other environmental factors. The experimental design literature contains very important contribution toward this aim, largely using randomization of treatments to plots to enable an analysis without modeling plot effects. The randomized complete block design, because of its simplicity, continues to be a popular choice for many variety trials. The precision of block analyses relies on the control of heterogeneity within blocks. Generally, the greater the heterogeneity within blocks, the poorer the precision of variety effect estimates. Therefore incomplete block designs become more popular in varietal trials.

Ma and Harrington (1948) during the period 1937 and 1946 used a total of 81 lattices of various kinds in Saskatoon and Tisdale experiments at the University of Saskatchewan. The precision gains of the lattices over randomized blocks were 28% for simple, 60% for triple, 63% for quadruple, 98% for balanced lattices, 32% for lattice squares and 45% for balanced incomplete blocks. The averaged increased efficiency of lattices over randomized blocks was 48%. While in a study of 244 UK cereal trials, Patterson & Hunter (1983) showed that the variances of varietal yield differences from using alpha-lattice were, on average, 30% lower than for CBDs. They conclude that the lattice designs are most effective when the number of varieties is more than 50, but worthwhile reduction in variance averaging about 24% were obtained in trials with fewer than 20 varieties. They represent an average efficiency of 1.43 over all 244 trials.

Yau (1997) has used an alpha-lattice design in 714 international yield trials of barley durum wheat and bread wheat in 1990/91 to 1992/93 resulted in an average efficiency 18% higher than the RCBD while using average variance as the comparison criterion.

Alpha-lattice was generally most efficient when the C.V's. of trials were high. It is also slightly more efficient for low yielding than for high yielding trials, and for rain fed than for irrigated trials.

MATERIALS AND METHODS

For this study data sets on wheat uniformity trials were taken from three research stations in Pakistan, one from National Agricultural Research Council (NARC) Islamabad: second from Barani Agricultural Research Institute (BARI) Chakwal: and third from Ayub Agricultural Research Institute (AARI) Faisalabad. Trials were harvested using a plot size of 1x1 m comprising 400 unit plots.

This study was primarily focused on characterizing soil heterogeneity in field uniformity trials. Based on the premise that, uniform soil when cropped uniformly will produce a uniform crop, soil heterogeneity can be measured as the differences in performance of plants grown in a uniformly treated area. Several types of analyses are available to evaluate the pattern of soil heterogeneity based on uniformity trials. In this study, soil productivity contour maps were used to present soil heterogeneity. The map describes graphically the productivity level of the experimental site based on moving averages of contiguous plots.

The importance of soil heterogeneity as a source of experimental error was extensively studied during the first thirty years of 20th century. The use of autocorrelation for testing the independent nature of data was prevailed for comparing various sizes and shapes of plots up to 1950, (Li and Keller, 1951). To illustrate the presence of trend in field and to decide about the appropriate plot and block size (dimension), autocorrelations were calculated for original plot size and for larger plots (after combining small plots), because 1x1m plot size was too small for field trials. If field variation is known, the use of long and narrow plots with the longer dimension in the direction of greatest variation can help to reduce effects of field heterogeneity (Li and Keller, 1951).

Methods for controlling variability

In 1926, R. A. Fisher in his first paper on field experimental designs emphasized 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 efficiency of the RCB design is not high. The problem with complete blocking is that as the block size increases due to the increase in the number of treatments, the homogeneity of experimental plots within a large block is difficult to maintain and thus local control of experimental variability becomes inefficient. Therefore if the block size and shape is not appropriately chosen, or if the block size is too large, the resulting experiment may not be a well controlled experiment in terms of variability and thus will provide inefficient results. Sometimes, especially when there are a lot of treatments, it is difficult or impossible to fit all of the treatments into one block of homogeneous units. For a long time the methods used to overcome this difficulty were:

- Confounding one or more factorial contrasts with blocks
- Use split plot designs which in effect confound a factorial main effect

This reduction in the size of block was achieved by sacrificing all or part of the information on certain treatment comparisons to achieve more precision on some others. But in situations where there are a large number of treatments and it is desired to make all comparisons among pairs of treatments with equal precision, a different method for reducing the block size is employed, that is known as incomplete block design (IBD).

More efficient designs for variety trials would be incomplete block designs which divide each complete block into smaller blocks. These designs are arranged in blocks or groups that are smaller than a complete replication, in order to eliminate heterogeneity, to a greater extent than of randomized complete block design. This prompted Yates (1936) to introduce lattice designs for such trials. However, it was not until Patterson & Williams (1976) extended Yates' method of construction to remove restrictions on numbers of varieties and to generate generalized lattice designs (Alpha designs), with widespread use made of incomplete block designs in variety trials. Generalized lattice designs are resolvable. If there is no gain in precision due to reduction in block size, these designs can be reanalyzed as if they were ordinary randomized complete blocks. All the analyses in this study were performed with the computer program Genstat-5.

RESULTS AND DISCUSSION

Contour maps of data from three research stations are shown in Figure-1(a-c). The three maps are somewhat different from one another, particularly in the fertility direction. The map for NARC field trial showed a unidirectional fertility gradient. Map seems to capture the trough of high yield in the upper portion of the field. If blocks are constructed in horizontal direction, it seems logical that similar plots have to be in the same block. The map of BARI research station showed that yield increases from left side to the center of the field and then decreases from center to the right portion. Four patches of highest yield were prominent and occurred in the center and right bottom portion. The map of AARI research station showed that this site has high yield on the whole. Slow decrease in yield was observed from upper right portion to bottom right and a tendency of high yield was observed for some plots.

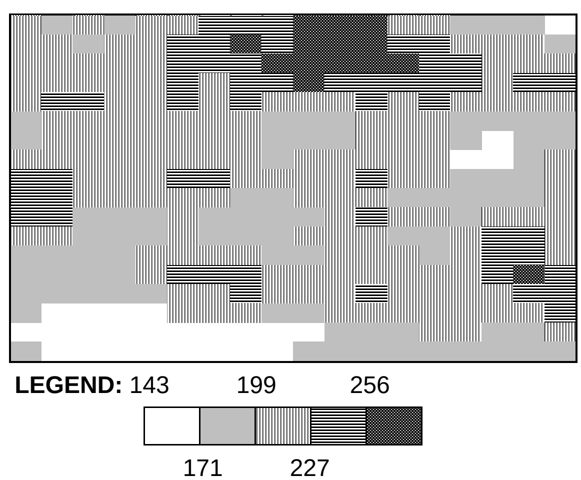

Fig. 1(a). NARC Contour Map

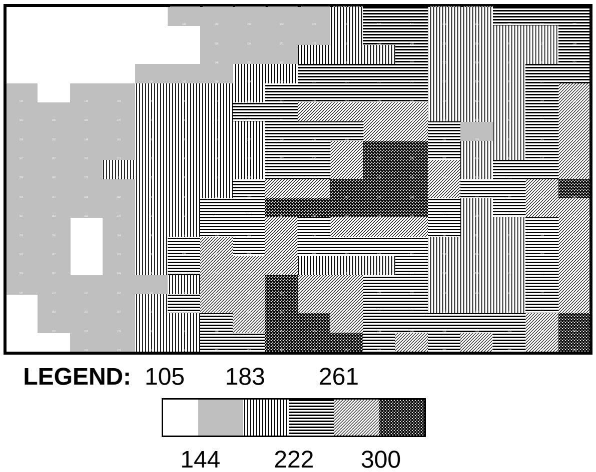

Fig. 1(b). BARI Contour Map

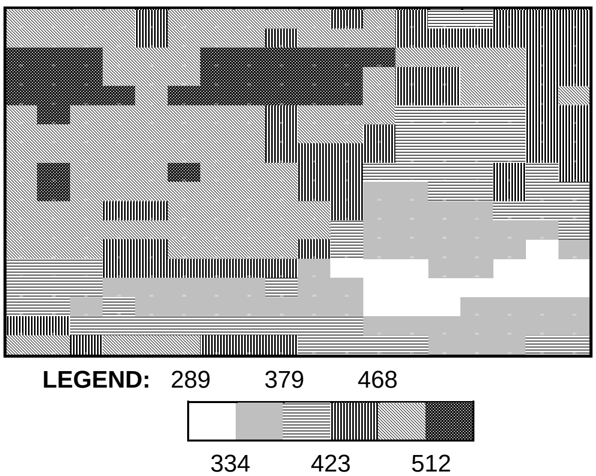

Fig. 1(c). AARI Contour Map

Analyses of wheat uniformity trials

To illustrate the presence of trend in field, the autocorrelations were calculated for original plot size and for larger plots after combining small plots. These autocorrelations helps in deciding the appropriate plot and block size (dimension). For all three research stations, the autocorrelations up to lag-5 are presented in Tables-1(a-c).

For all three data sets there was a rather high correlation between adjacent plots. Each of the lag-1 and lag-2 correlations was significantly different from zero and there was typically stronger correlation in one direction than in the other.

At NARC, columns autocorrelations were significant only at lag-1 while rows autocorrelations were significant up to lag-5. So, we may decide a plot of size 1x5 in basic units. However it is just a crude decision, so different reasonable plot and blocks are considered to choose the ones with highest efficiency.

Table 1(a). Autocorrelations for NARC site

Plot size	Autocorrelations at lag				
	1	2	3	4	5
1 x 1 Row	0.15*	0.14*	0.15*	0.10*	0.12*
1 x 1 ol	0.31**	0.11	-0.03	-0.05	-0.06
1 x 4 Row	0.36**	0.17	0.15	0.18	0.45**
1 x 4 Col	0.46**	0.21*	-0.12	-0.20*	-0.21*
1 x 5 Row	0.34**	0.08	0.12	0.49**	0.23*
1 x 5 Col	0.50**	0.21*	-0.09	-0.20*	0.19
2 x 5 Row	0.26	-0.03	0.02	0.31*	0.15
2 x 5 Col	0.30*	-0.23	-0.22	-0.10	0.02

* Significant at 5%, ** Significant at 1%

Table 1(b). Autocorrelations for BARI site

Plot size	Autocorrelations at lag				
	1	2	3	4	5
1 x 1 Row	0.41**	0.22*	0.12*	0.09	0.06
1 x 1 Col	0.65**	0.56**	0.49**	0.42**	0.39**
1 x 4 Row	0.20*	-0.19*	-0.19*	0.14*	0.75**
1 x 4 Col	0.79**	0.67**	0.61**	0.57**	0.55**
1 x 5 Row	0.10	-0.34**	0.06	0.77**	0.06
1 x 5 Col	0.80**	0.71**	0.61**	0.56**	0.52**
2 x 5 Row	0.12	-0.39**	-0.01	0.71**	0.01
2 x 5 Col	0.78**	0.62**	0.55**	0.55**	0.49**

* Significant at 5%, ** Significant at 1%

Table 1(c). Autocorrelations for AARI site

Plot size	Autocorrelations at lag				
	1	2	3	4	5
1 x 1 Row	0.58**	0.48**	0.43**	0.44**	0.34**
1 x 1 Col	0.43**	0.40**	0.19*	0.25*	0.19*
1 x 4 Row	0.59**	0.35*	0.27*	0.44**	0.60**
1 x 4 Col	0.60**	0.53**	0.34*	0.33*	0.23*
1 x 5 Row	0.57**	0.25*	0.43**	0.59**	0.37*
1 x 5 Col	0.60**	0.49**	0.32*	0.36*	0.27
2 x 5 Row	0.56**	0.22	0.43*	0.62**	0.35*
2 x 5 Col	0.62**	0.44*	0.19	0.01	-0.15

* Significant at 5%, ** Significant at 1%

On the other hand autocorrelations were high in both directions for BARI and AARI sites with unit plot size. Autocorrelation for different plot sizes are also shown in Table-1(a-c). For plot of size 1 x 5, there is high autocorrelation up to lag-5 in column direction while in row direction autocorrelation present in spikes. From this information we may decide a block of size 5 x 1 (i.e. in original units a block of size 5 x 5). An important point to note for each plot size is that, column's autocorrelations are high up to lag-5 but in rows there are spikes of high correlations. Results of Patterson and Hunter (1983) indicate that blocks of no more than 10 plots overall, and the optimum is likely to lie between 5 and 10 plots.

After taking some idea about plot/block size and shape from autocorrelations, generalized lattice design was superimposed and the final decision about plot/block size and shape for each site was taken on the basis of efficiency factor.

Design plans for uniformity trials

Different design layouts were superimposed with different number of treatments, replicates, number of plots per block and with various block sizes to see if the shape (size) of the plots (blocks) affects the efficiency of design. The original plots were square in shape (1 x 1 m^2) and larger plots were constructed by combining unit rows and columns. The different arrangements of columns and rows into larger plots resulted in a total of 18 layout plans, corresponding to various combinations of plot size/shape, block size/shape and the number of dummy treatments. Replicates were vertical or horizontal in shape. Different design layouts for three sites with complete description are given in Tables-2(a-c).

effects, it will have smaller errors and variances than that of CBD, so that the efficiency of generalized lattice design relative to CBD will be larger than 1.0.

Because the efficiencies of the postblocked analysis partly depends on the randomization chosen, so for each layout plan, 15 randomizations were applied to avoid any bad/good randomization by using ALPHA+ programmed by CIMMYT (1993). Average efficiencies of Alpha design over RCBD with different layouts are given below in Table-3 (a-c).

Tables-3(a-c) showed that the effectiveness of different layouts has varied markedly between trials. A reduction of more than 50% in the standard error of difference was achieved in some layout plans, whereas there are some layouts, where reduction in standard error was slightly worse. One of the objectives of this study was to demonstrate that complete blocking system often performs poorly in their function of reducing experimental error.

The reduction in standard error of treatment differences at all three research stations makes it worthwhile to use alpha-lattice instead of the RCB in field trials. The proposed designs are easy to implement as they do not need any changes in field layout or major additional input. At NARC, two plans present more than 50% reduction in SEDs, while seven out of 18 plans shows a reduction of more than 50% at BARI research station. Not much gain has been achieved at AARI site, as only one plan shows a reduction of more than 50%.

Table 2(a). Superimposed design layouts for NARC uniformity trial

Layout No.	Plot size	No. of plots	No. of replicate and shape	No. of plot/block	No. of treat.	No. of block/rep.	Block size
1	2 x 5	40	2 (V)	4	20	5	4 x 10
2	2 x 5	40	2 (V)	5	20	4	10 x 5
3	2 x 5	40	2 (H)	5	20	4	10 x 5
4	2 x 5	40	2 (H)	4	20	5	2 x 20
5	1 x 5	80	2 (H)	5	40	8	5 x 5
6	1 x 5	80	4 (H)	4	20	5	1 x 20
7	1 x 5	80	4 (V)	4	20	5	4 x 5
8	1 x 5	80	4 (V)	5	20	4	5 x 5
9	1 x 5	80	2 (H)	10	40	4	10 x 5
10	1 x 5	80	2 (H)	8	40	5	2 x 20
11	1 x 5	80	2 (V)	10	40	4	5 x 10
12	1 x 5	80	2 (H)	10	40	4	5 x 10
13	1 x 4	100	5 (H)	5	20	4	1 x 20
14	1 x 4	100	4 (H)	5	25	5	1 x 20
15	1 x 4	100	2 (H)	5	50	10	1 x 20
16	1 x 4	100	5 (V)	5	20	4	5 x 4
17	1 x 4	100	5 (V)	4	20	5	4 x 4
18	1 x 4	100	5 (V)	10	20	2	10 x 4

Efficiency of different design structures

Efficiencies of the generalized lattice designs were calculated as described by Yates (1939) for the original lattice designs. The efficiency of the generalized lattice design is given by the average variance of varietal differences in analysis of CBD divided by the average variance of varietal differences in analysis of generalized lattice design. If generalized lattice design is adequately modeled and adjusted for environmental

Table 2(b). Superimposed design layouts for BARI uniformity trial

Layout No.	Plot size	No. of plots	No. of replicate and shape	No. of plot/block	No. of treat.	No. of block/rep.	Block size
1	2 x 5	40	2 (V)	4	20	5	4 x 10
2	2 x 5	40	2 (H)	4	20	5	2 x 20
3	2 x 5	40	2 (H)	5	20	4	10 x 5
4	2 x 5	40	2 (V)	5	20	4	10 x 5
5	1 x 4	100	5 (V)	5	20	4	10 x 5
6	1 x 4	100	2 (H)	10	50	5	10 x 4
7	1 x 4	100	5 (V)	4	20	5	4 x 4
8	1 x 4	100	5 (H)	4	20	5	4 x 4
9	1 x 4	100	2 (H)	10	50	5	2 x 20
10	1 x 5	80	2 (V)	5	40	8	5 x 5
11	1 x 5	80	2 (V)	10	40	4	5 x 10
12	1 x 5	80	2 (V)	8	40	5	4 x 10
13	1 x 5	80	2 (H)	5	40	8	5 x 5
14	1 x 5	80	2 (H)	10	40	4	5 x 10
15	1 x 5	80	4 (H)	4	20	5	1 x 20
16	1 x 5	80	2 (H)	4	40	10	1 x 20
17	1 x 5	80	2 (H)	8	40	5	2 x 20
18	1 x 5	80	4 (V)	4	20	5	4 x 5

H: Horizontal direction V: Vertical direction

Table 2(c). Superimposed design layouts for AARI uniformity trial

Layout No.	Plot size	No. of plots	No. of replicate and shape	No. of plot/block	No. of treat.	No. of block/rep.	Block size
1	2 x 5	40	2 (H)	5	20	4	10 x 5
2	2 x 5	40	2 (H)	4	20	5	2 x 20
3	2 x 5	40	2 (V)	4	20	5	4 x 10
4	2 x 5	40	4 (V)	2	10	5	2 x 10
5	1 x 5	80	5 (H)	4	16	4	1 x 20
6	1 x 5	80	2 (H)	8	40	5	1 x 20
7	1 x 5	80	4 (H)	4	20	5	1 x 20
8	1 x 5	80	4 (V)	4	20	5	10 x 10
9	1 x 5	80	4 (V)	5	20	4	4 x 5
10	1 x 5	80	2 (V)	5	40	8	5 x 5
11	1 x 5	80	2 (H)	5	40	8	5 x 5
12	1 x 5	80	2 (H)	10	40	4	5 x 10
13	1 x 4	100	4 (H)	5	25	5	1 x 20
14	1 x 4	100	5 (H)	5	20	4	1 x 20
15	1 x 4	100	2 (H)	10	50	5	2 x 20
16	1 x 4	100	2 (H)	5	50	10	1 x 20
17	1 x 4	100	2 (H)	10	50	5	10 x 4
18	1 x 4	100	5 (V)	5	20	4	5 x 4

Table 3(a). Average efficiency of Alpha design over RCB for NARC

Layout No.	Average R.E	% reduction	Layout No.	Average R.E	% reduction
1	1.14	12	10	1.16	14
2	1.43	30	11	1.12	11
3	1.11	10	12	1.10	9
4	1.17	15	13	1.11	10
5	1.05	5	**14**	**2.23**	**55**
6	1.10	9	15	1.12	11
7	1.09	8	16	1.15	13
8	2.18	54	17	1.03	3
9	1.08	7	18	1.54	35

Table 3(b). Average efficiency of Alpha design over RCB for BARI

Layout No.	Average R.E	% reduction	Layout No.	Average R.E	% reduction
1	1.05	5	10	2.17	54
2	1.15	13	11	1.35	26
3	**3.64**	**73**	12	1.27	21
4	2.64	62	**13**	**3.61**	**72**
5	1.53	35	14	1.45	31
6	2.79	64	15	1.87	47
7	1.48	32	16	1.79	44
8	2.26	56	17	1.19	16
9	1.71	42	18	2.25	56

Table 3(c). Average efficiency of Alpha design over RCBD for AARI

Layout No.	Average R.E	% reduction	Layout No.	Average R.E	% reduction
1	1.36	26	10	1.19	16
2	1.53	35	11	1.18	15
3	1.46	32	12	1.22	18
4	**2.33**	**57**	13	1.22	18
5	1.17	15	14	1.05	5
6	1.07	7	15	1.23	19
7	1.19	16	16	1.24	19
8	1.23	19	17	1.39	28
9	1.37	27	18	1.31	24

SUMMARY AND CONCLUSION

In this study, it was tried to impose an incomplete block experiment in the field by using uniformity trials experimental data. It was tried to impose complete (incomplete) block designs with different number of parameters, so that the plots within same block are consistent. The results showed that generalized lattices were on the average more efficient in reducing the experimental error and hence provide the efficient estimation of treatment contrasts. It is recommended that before doing any variety trials at a new field, field variability must be studied by conducting a uniformity trial to see the patterns of fertility in the experimental field. Then use an appropriate design (complete or incomplete) but it is suggested to apply an incomplete block designs which are, if appropriately adopted, always efficient than complete block designs.

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