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Efficiency of alpha lattice design over RCBD in evaluation of maize (*Zea Mays* L.) Hybrids

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ABSTRACT

Precise evaluation of genotypes is necessary in any field trials for selecting desirable genotypes for given traits. Blocking is a cost effective tool in increasing the efficiency of experimental design without any economic cost. In the current trial, sixty three maize hybrids were evaluated in 9 x 7 alpha lattice designs with three replications. The field data collected on twelve quantitative characters was analysed through for both alpha lattice and randomized complete block design (RCBD) to compare the efficiency. Coefficient of variation of grain yield for alpha lattice was lower 14.51 as compared to 17.59 in RCBD. Similarly, error mean sum of squares was lowest for alpha lattice design than RCBD for all the measured traits expect cob length and shelling percentage. Alpha lattice was useful in evaluating traits such as ear height, plant height and grain yield than RCBD due to lower error variance of the latter design. Whereas RCBD showed slightly better than Alpha lattice in evaluating traits viz., ear length, shelling percent and number of kernel rows.

Key words: Maize, Alpha lattice, Blocking, least square difference, RCBD

INTRODUCTION

Every plant breeding trial needs to have a specific experimental design for accurate comparison of treatment means and to reduce noise arising from various external factors *viz*., environmental factors and management practices. Fisher laid three basic principles of experimental designs viz., randomization, replication and local control which serve as the basis for all experimental designs. Randomized complete block design (RCBD) is the most common design used by plant breeders in evaluation of agriculture field trials due to its simplicity, ease of layout and statistical analysis. However, the drawback of the design is reduced efficiency because of higher error variance value when the number of treatments/ entries /genotypes increase and when there is heterogeneity in environmental conditions (Lentner and Bishop 1993). To overcome this drawback of higher error variance while evaluating large number of entries, Yates during 1930's introduced lattice designs which followed a one way blocking technique. Various lattice designs such as simple, square, cubic lattice designs were utilized to handle a large number of entries. But, these designs were inflexible in terms of number of entries/treatments to be evaluated and has more restrictions for field layout i.e., a square lattice would require number of entries to be square number 16, 25, 36 etc., whereas cubic lattice would require number of entries to be cube number 9, 64, 100 etc. These aspects prevented them from being widely used.

Later, this problem was addressed by Patterson and Williams (1976) who introduced new type of resolvable and partially balanced lattice design called alpha lattice. This design can practically handle any number of entries where the number of entries should be multiple of *b* blocks and *k* number of plots within replication. Patterson and Hunter (1983) and Pilarczyk (1991) have shown that alpha lattice is more efficient than RCBD in field trials. Cochran and Cox (1957) revealed that lattice designs can be arranged in complete replications as well as incomplete blocks. Since, replications can be followed in alpha lattice such designs may be regarded as randomized block designs which have additional restrictions within each replication. Yates (1936) has shown that these designs can be analyzed as if they were ordinary randomized complete blocks.The efficiency of one analysis over another is usually measured in terms of reduced error variance, expected error mean squares or standard error of the difference between genotype means (Cochran and Cox, 1957, Binns 1987 and Magnussen 1990). Thus, in the present study it was intended to measure the efficiency of alpha lattice design over RCBD.

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MATERIAL AND METHODS

The present field study was on evaluation of 63 maize hybrids in 9 x 7 alpha lattice design during *kharif* 2021 at AICRP Maize, University of Agricultural Sciences, Dharwad (Karnataka). The trial included 60 single cross test hybrids and three commercial checks namely GPMH-1101 (Local check), 900 M GOLD (Private Check) and NK-6240 (National Check). Each entry was raised in two rows of 4 meter length with row to row spacing of 60 cm and plant to plant spacing of 20 cm. Two seeds were sown per hill and later through thinned to a plant population of 83,333. Recommended package of practice was followed to raise a healthy crop. Twelve morphological and yield attributing traits were collected during appropriate plant growth stages. Traits days to 50% anthesis, days to 50% silking, days to maturity and grain yield were recorded on plot basis whereas, other traits *viz*., plant height, ear height, number of kernel rows, number of kernels per row, cob length, cob girth and shelling percentage were recorded on five plant/cob.

Statistical Analysis

An observation was recorded on twelve quantitative characters and was analyzed as per lattice and randomized complete block design. The RCBD linear fixed model is as follows,

$$Y_{ij} = \mu + r_i + t_j + e_{ij}$$

where, Y_{ijk} is observed mean of j^{th} treatment in i^{th} replication, μ is general mean, r_i is fixed effect of replicate i and tj is effect of treatment j.

Similarly, the general linear model fitted for alpha lattice is as follows,

$$Y_{ijk} = \mu + r_i + b_{ij} + t_k + e_{ijk}$$

where Y_{ijk} is the observed mean of k^{th} treatment in j^{th} block and i^{th} replication, μ is the general mean, r_i is the fixed effect of replicate i, b_{ij} is block j within replicate and t_k is effect of treatment k. The coefficient of variation (CV) is calculated using formula CV = μ/σ_e^2 x 100.

To compare the mean performance of two genotypes Fishers LSD (Least significant difference) was estimated as follows,

$$LSD = t_{\alpha/2,edf} \times SED$$

where, $t_{\alpha/2,edf}$ is or a significance level of α/2 at error degrees of freedom (edf) and SED is the standard error of a difference between two means. The significance was estimated at α = 0.05. The SED is calculated as $\sqrt{2\sigma_e^2/r}$ where σ_e^2 is error variance and r is the number of replications.

The efficiency of two designs was compared using two methods i.e., comparing the error variance and LSD values of designs. The error variance is compared as,

$$E_{error} = RCBD\ \sigma_e^2 / ALPHA\ \sigma_e^2 \times 100$$

Where, RCBD σ_e^2 is the error variance from RCBD analysis and ALPHA σ_e^2 is the error variance from alpha lattice design. The relative efficiency (RE) of alpha lattice over RCBD is estimated as,

$$RE = RCBD\ \sigma_e^2 – ALPHA\ \sigma_e^2 / RCBD\ \sigma_e^2 \times 100$$

In an another method LSD of the respective experiments are compared as follows,

$$E_{LSD} = LSD_{RCBD} / LSD_{alpha} \times 100$$

The LSD (Least significant difference) was used for comparing mean performance of two genotypes and was estimated as follows,

$$LSD = t_{\alpha/2,edf} \times SED$$

where, $t_{\alpha/2,edf}$ is or a significance level of α/2 at error degrees of freedom (edf) and SED is standard error of a difference between two means. SED is calculated as $\sqrt{2\sigma_e^2/r}$ where σ_e^2 is error variance of the design and r is number of replications. All statistical analysis was done using SPSS v12 (IBM Corp, 2017)

RESULTS AND DISCUSSION

Average grain yield ranged from 21.11 q/ha (GH-1617) to 84.64 q/ha (GH-1658) with a mean grain yield of 52.41 q/ha (Table 1). The CV for grain yield as per RCBD was 17.59 and that for alpha lattice was comparatively low with a value of 14.51. For yield attributing traits CV_{RCBD} was slightly higher than CV_{ALPHA} except for cob length. For grain yield and ear length using alpha lattice resulted in greater increase in accuracy as seen by lower coefficient of variation values.

Table 1: Mean, range and coefficient of variation for twelve morphological and yield attributing traits in maize

Traits	Days to 50 % anthesis (days)	Days to 50 % silking (days)	Days to maturity (days)	Plant height (cm)	Ear Height (cm)	No. of kernel rows	No. of kernels per row	Cob girth (cm)	Cob length (cm)	Hundred seed weight (g)	Shelling percentage (%)	Grain yield (q/ha)
Minimum	53.00	53.00	68.00	144.00	50.40	10.33	22.00	2.21	11.90	16.84	74.57	21.11
Maximum	75.00	75.00	123.00	225.00	114.00	18.00	44.33	5.33	20.40	33.14	93.10	84.64
Mean	62.80	64.53	103.76	184.20	89.04	14.67	34.54	4.50	16.84	25.43	83.78	52.41
CV_{RCBD}	6.04	5.41	6.26	5.74	10.45	5.42	7.66	17.54	1.22	6.48	1.62	17.59
CV_{ALPHA}	5.59	5.06	6.04	4.71	6.87	5.41	6.92	15.86	1.23	6.26	1.62	14.51

Analysis of Variance

The result from ANOVA for both RCBD and alpha lattice is presented in Table 2. Hybrid variance was significant for all the twelve traits under both the experimental designs. Replication variance was significant for six traits viz., days to maturity, number of kernel rows, number of kernels per row, cob length, cob girth and hundred seed weight for both RCBD and alpha lattice analysis. Whereas, block within replication variance was significant for eight traits viz., days to anthesis, days to silking, plant height, ear height, number of kernels per row, cob length, hundred seed weight and grain yield. The issue of large block is that as the block size increases it is difficult to maintain homogeneity of experimental plots (Stroup *et al.,* 1994). This indicates the importance of blocking (local control) to reduce soil heterogeneity and accurate comparison of treatment means.

Table 2: ANOVA: comparison of mean sum of squares-Alpha lattice *vs* RCBD for twelve morphological and yield attributing traits

Source of variation	df	Days to 50 % anthesis		Days to 50 % silking		Days to maturity		Plant height		Ear height		No. of kernel rows	
		Alpha	RCBD	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD
Replication	2	4.926	4.93	7.307	7.31	140.76*	140.76*	146.31	146.31	28.51	28.51	1.98*	1.98*
Block with Replication	24	22.91*		18.61*		54.29		265.08**		291.62**		0.64	
Genotypes	62	35.29**	42.43**	38.71**	46.04**	67.34**	73.62**	498.07**	635.76**	150.20**	228.63**	2.93**	3.38**
Error	100 (124)	12.32	14.37	10.67	12.21	39.32	42.21	75.23	111.97	37.42	86.62	0.63	0.63

	No. of kernels per row		Cob length (cm)		Cob girth (cm)		Hundred seed weight (g)		Shelling percentage		Grain yield	
	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD	Alpha	RCBD
Replication	92.29*	92.29**	13.10*	13.10**	0.26*	0.26**	51.39*	51.39**	0.68	0.68	103.32	103.32
Block with Replication	12.36**		1.10**		0.04		3.46**		1.83		198.27**	
Genotypes	26.23**	30.96**	4.13**	5.18**	0.19**	0.22**	17.55**	21.21**	7.43**	10.62**	213.77**	300.01**
Error	5.71	6.99	0.51	0.62	0.04	0.04	2.53	2.71	1.84	1.84	57.81	85

*Note: * significance at P ≤ 0.05, ** significance at P ≤ 0.01*

Efficiency of designs

Results of comparison of both the design by error variance is presented in Table 3. Alpha lattice was more efficient for all the traits except for cob girth and shelling percentage for which RCBD σ_e^2 was lower than ALPHA σ_e^2. For ear length alpha lattice was a huge improvement over RCBD followed by plant height and grain yield whereas, for number of kernel rows, days to maturity and hundred seed weight alpha lattice showed only marginal improvement. Relative efficiency represents gain in accuracy of alpha lattice over RCBD design meaning a value of 56.80 % RE for ear length represents a three replication in RCBD is equivalent to two replication in alpha lattice. Similarly, RE of 33 % plant height and grain yield means 4 replications in alpha lattice is equivalent to 5.6 replications in RCBD. Relative efficiency for traits days to maturity, number of kernel rows, cob girth, hundred seed weight and shelling percentage was marginal to negligible. Additionally, Yau (1997) in wheat and barley, Akinwale *et al* (2021) in maize and Abdelkawy *et al.* (2020) in triticale reported similar findings.

Table 3: Comparison of RCBD and alpha lattice using error variance and relative efficiency of alpha lattice design

Traits	RCBD σ_e^2	ALPHA σ_e^2	E_{error}	Relative efficiency
Days to 50 % anthesis	14.37	12.32	116.62	14.25
Days to 50 % silking	12.21	10.67	114.40	12.59
Days to maturity	42.21	39.32	107.37	6.87
Plant height	111.97	75.23	148.84	32.81
Ear height	86.62	37.42	231.49	56.80
No. of kernel rows	0.63	0.63	100.32	0.32
No. of kernels per row	6.99	5.71	122.55	18.40
Cob girth	0.62	0.51	122.35	18.27
Cob length	0.04	0.04	97.67	-2.38
Hundred seed weight	2.71	2.53	107.11	6.63
Shelling percentage	1.84	1.84	99.84	-0.16
Grain yield	85.00	57.81	147.03	31.99

Both the designs were also compared using LSD values of the respective experiments (Table 4). The sixty three test hybrids can form a total of 3,906 pair wise mean combinations. For grain yield, 1,140 and 1,520 combinations were significant for RCBD and alpha lattice analysis respectively. Thus, 9.73 % more pair wise combinations of hybrid mean were found to be significant at $P \leq 0.05$. Obviously, ear length recorded the highest 21.20 % change in significant pair wise mean comparison from 894 (RCBD) to 1,722 (alpha lattice). Negligible change in significant pair wise combinations was observed for number of kernel rows, cob length and shelling percentage. For grain yield and plant height ~9 % more pairwise combinations were found to be significant under alpha lattice design. Therefore, alpha lattice is an efficient design for traits such as ear height, grain yield and plant height as revealed by high E_{LSD} values. These results highlight the usefulness of alpha lattice design in comparing mean of genotypes to make meaningful inference. New significant pair wise combinations were revealed in alpha lattice design which would be helpful for breeders in making selection. If the experimental materials are highly variable, lattice design helps in most accurate comparison of genotype mean (Cochran and Cox, 1957).

Table 4: Count of significant pair wise comparison of hybrid mean using RCBD and alpha lattice analysis

Traits	RCBD*	Alpha lattice*	Per cent change	LSD_{RCB}	LSD_{alpha}	E_{LSD}
Days to 50 % anthesis	1,044	1,152	2.76	6.13	5.69	107.73
Days to 50 % silking	1,342	1,492	3.84	5.65	5.29	106.71
Days to maturity	521	566	1.15	10.50	10.16	103.38
Plant height	1,620	1,978	9.17	17.10	14.05	121.71
Ear height	894	1,722	21.20	15.04	9.91	151.79
No. of kernel rows	1,644	1,644	0.00	1.28	1.28	99.92
No. of kernels per row	1,430	1,576	3.74	4.27	3.87	110.44
Cob girth	1,394	1,306	-2.25	1.28	1.16	110.35
Cob length	2,140	2,140	0.00	0.33	0.34	98.60
Hundred seed weight	1,859	1,915	1.43	2.66	2.58	103.25
Shelling percentage	1,456	1,463	0.18	2.19	2.20	99.68
Grain yield	1,140	1,520	9.73	14.90	12.32	120.97

*Note: * significance at P ≤ 0.05*

Accurate comparison of genotypic means helps breeder in making practical decisions which can be achieved by reducing the error variance of the experiment. Along with replication and randomization, local control is an efficient tool in increasing the efficiency of experiments.

The outcome of the present study reconfirms that alpha lattice design is more efficient than RCBD as the design reduced the error variance component, thereby the variance in the experiment can more reliable and the genotypic performance can be more realistic and this will assist the breeders in making the practical decision and selection. Moreover, alpha lattice design which is flexible w.r.t. the number of treatments than other lattice designs and incorporates one way blocking serves as an ideal experimental design for plant breeders to follow when the experimental material is large and precious.

REFERENCES

Abdelkawy, R.N.F., Turbayev, A.Z. and Soloviev, A. A. (2020) Evaluation of relative efficiency of alpha lattice design and cluster analysis of twenty spring triticale field experiments. *Indian Journal of Agricultural Research* **54**(3): 301-307.

Akinwale, R.O., Odunlami, L. K., Eze, C. E. and Oladejo, A. S. (2021) Effectiveness of different alpha lattice designs in the evaluation of maize (*Zea mays* L.) genotypes in a rainforest agro-ecology. *Heliyon*, **7**(7): 1-7.

Binns, M.R. (1987) Practical use of neighbour methods and alternatives in the analysis of field trials. *Canadian Journal of Plant Science* **67**: 477-489.

Cochran, W.G. and Cox, G.M. (1957) Experimental Designs, 2nd ed. Wiley, New York.

IBM Corp. (2017) IBM SPSS Statistics for Windows. Armonk, NY: IBM Corp.

Lentner, M. and Bishop, T. (1993) Experimental Design and Analysis, 2rd Edition. Valley Book Company, Blackburg, VA.

Magnussen, S. (1990) Application and comparison of spatial models in analyzing tree- genetics field trials. *Canadian Journal of Forest Research* **20**: 536-546.

Patterson, H.D. and Williams, E.R. (1976) A new class of resolvable incomplete block designs. *Biometrika* 63, 83-92.

Patterson, H.D. and Hunter, E.A. (1983) The efficiency of incomplete block designs in national list and recommended list of cereal variety trials. *The Journal of Agricultural Science*, **101**:427–433.

Pilarczyk, W. (1991). The efficiency of alpha-designs in Polish variety testing field trials. *Plant Varieties and Seeds*, **4**(1): 37-41.

Stroup, W. W., Baenziger, P.S. and Mulitze, D.K. (1994) Removing spatial variation from wheat yield trials: a comparison of methods. *Crop Science* **86**: 62-66.

Yates, F. (1936) A new method of arranging variety trial involving a large number of varieties. *Journal of Agricultural Science*, 26: 424-455.

Yau, S. K. (1997) Efficiency of alpha-lattice designs in international variety yield trials of barley and wheat. *The Journal of Agricultural Science*, **128**(1): 5–9.