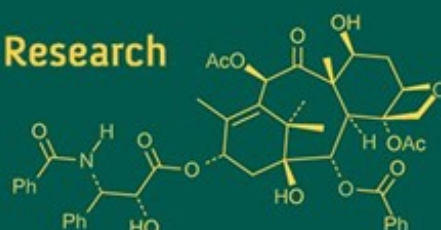
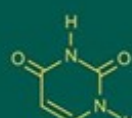


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**SJ Devra**

Department of Agricultural  
 Statistics, CoA, J.A.U.,  
 Junagadh, Gujarat, India

**MS Shitap**

Department of Agricultural  
 Statistics, CoA, J.A.U.,  
 Junagadh, Gujarat, India

**DV Patel**

Department of Agricultural  
 Statistics, CoA, J.A.U.,  
 Junagadh, Gujarat, India

**PV Chovatiya**

Department of Agricultural  
 Statistics, CoA, J.A.U.,  
 Junagadh, Gujarat, India

## Relative efficiency of experimental designs for improving precision in groundnut field experiments

SJ Devra<sup>1</sup>, MS Shitap<sup>2</sup>, DV Patel<sup>3</sup>, PV Chovatiya<sup>4</sup>

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**ABSTRACT**

The present study was undertaken to evaluate the relative efficiency of different experimental designs for conducting groundnut field experiments under heterogeneous field conditions. Uniformity trial data of two groundnut varieties, GJG-32 and GJG-19, collected during Kharif 2024 at Junagadh Agricultural University, Gujarat, were used for the comparison. The relative efficiency of Completely Randomized Design (CRD), Randomized Complete Block Design (RCBD), Latin Square Design (LSD), simple lattice, triple lattice and balanced lattice designs was assessed at block sizes of 4 and 5. For GJG-32, the balanced lattice design recorded relative efficiencies of 106.30 and 111.09 per cent at block sizes 4 and 5, respectively. For GJG-19, the balanced lattice design recorded 111.03 and 104.34 per cent at block sizes 4 and 5, respectively. The results indicated that the efficiency of experimental designs varied with the groundnut variety and block size. Lattice designs generally provided improved precision over RCBD under the evaluated conditions, with balanced lattice showing consistently high efficiency across the combinations studied. The findings highlight the importance of selecting an appropriate experimental design according to field variability and treatment structure to improve the precision and reliability of groundnut field experiments.

**Keywords:** Groundnut, Relative efficiency, Experimental design, RCBD, Lattice design

**1. Introduction**

Agricultural field experiments are conducted to compare treatments, varieties, agronomic practices and management technologies under field conditions. The validity of conclusions obtained from such experiments depends strongly on the precision with which treatment effects are estimated. Field variability arising from differences in soil fertility, moisture availability, topography and other environmental factors contributes substantially to experimental error. Consequently, selection of an appropriate experimental design is one of the most important statistical decisions in field experimentation.

The randomized complete block design (RCBD) is widely used in agricultural experiments because blocking can account for one major source of field variability while maintaining a comparatively simple layout and analysis. However, when the number of treatments becomes large, a complete block may contain many experimental units and the assumption of homogeneity within the block may become less satisfactory. Under such conditions, incomplete block designs such as lattice designs can provide additional control of local field variability.

Lattice designs divide a replication into smaller incomplete blocks. Consequently, comparisons among treatments can be adjusted using information from smaller blocks, potentially reducing the effective experimental error when the experimental area is heterogeneous. Simple, triple and balanced lattice designs provide different levels of representation of the treatment-block relationships and may therefore differ in their ability to control experimental variability.

Latin square design (LSD) provides simultaneous control in two directions and can be useful where two important gradients of variation are present. However, its usefulness depends on the nature and direction of field variation and on the assumptions associated with the design. Comparison of LSD with CRD and RCBD therefore provides useful information regarding whether the additional blocking structure results in improved precision.

Previous studies have demonstrated that the efficiency advantage of incomplete block designs is particularly relevant under heterogeneous field conditions. Cochran (1941) [1] reported gains in accuracy from lattice and lattice-square arrangements. Lantin *et al.* (1976) [3] found relatively modest gains of LSD over RCBD in sugarcane experiments. Lin *et al.* (1993) [4] observed that RCBD was satisfactory when within-block variability was homogeneous, whereas lattice designs were more precise under heterogeneous conditions. Masood *et al.* (2008) [5] reported improved precision from alpha-lattice designs compared with RCBD in wheat experiments, while Raza *et al.* (2009) [6] reported gains in precision from lattice designs in rice experiments.

**Corresponding Author:****SJ Devra**

Department of Agricultural  
 Statistics, CoA, J.A.U.,  
 Junagadh, Gujarat, India

Groundnut is an important oilseed crop in Gujarat, and field experimentation on groundnut is frequently conducted under conditions where soil and environmental variability may influence experimental precision. Therefore, an evaluation of experimental designs using local uniformity-trial data is useful for identifying design structures that can effectively control experimental error.

The present study was undertaken to evaluate the relative efficiency of CRD, RCBD, LSD, simple lattice, triple lattice and balanced lattice designs using uniformity trial data for two groundnut varieties under the conditions of the Central Experimental Research Station (Sagadividi Farm), Junagadh Agricultural University, Junagadh.

## 2. Materials and Methods

### 2.1 Experimental site and crop material

Uniformity trials on groundnut varieties GJG 32 (Bunch type) and GJG 19 (Spreading type) were conducted during the *khari*f Season of 2024 to collect the necessary information for the investigation. The crop was grown with recommended agronomical practices at the Centre of Experimental Research Station (Sagadividi Farm), J.A.U., Junagadh.

| Sources                | d.f.       | Mean Square    |
|------------------------|------------|----------------|
| Replications           | (r - 1)    |                |
| Blocks in replications | r (k - 1)  | E <sub>B</sub> |
| Plots in blocks        | rk (k - 1) | E <sub>E</sub> |

where,

E<sub>B</sub> = inter-block mean square,

E<sub>E</sub> = intra-block or error mean square,

r = number of replications and

k = number of blocks in a replication.

Because no treatment effects present in the uniformity trial data, the analysis of variance reduces as presented above. For the same reason, the intra-block sum of squares does not require adjustment for the treatment effects, E<sub>B</sub> is fully efficient. The effective error mean square for the simple, triple and balanced lattice designs was:

$$\text{Simple lattice} = E_E \left[ 1 + \frac{2}{(k+1)} \left( \frac{E_B - E_E}{E_B + E_E} \right) \right], \text{ .....Eq. 1}$$

$$\text{Triple lattice} = E_E \left[ 1 + \frac{3}{(k+1)} \left( \frac{E_B - E_E}{2E_B + E_E} \right) \right], \text{ and .....Eq. 2}$$

| Sources | d.f.                 | Mean Square    |
|---------|----------------------|----------------|
| Rows    | (t - 1)              | E <sub>R</sub> |
| Columns | (t - 1)              | E <sub>C</sub> |
| Error   | (t - 1) <sup>2</sup> | E <sub>E</sub> |

Where,

E<sub>R</sub> = Row mean square,

E<sub>C</sub> = Column mean square,

E<sub>E</sub> = Error mean square and

t = number of columns/rows in a latin square.

The relative efficiency (RE) of a latin square design (LSD) as compared to a CRD is worked out by (Gomez *et al.*, 1984) [2],

$$RE \text{ (CRD)} = \frac{E_R + E_C + (t-1)E_E}{(t+1)E_E} \times 100 \text{ .....Eq. 4}$$

The relative efficiency of LSD as compared to RCBD is computed in two ways, viz., (i) considering rows as blocks and (ii) considering columns as blocks, of the RCBD. The relative efficiency is computed as,

$$RE \text{ (LSD, row)} = \frac{E_R + (t-1)E_E}{E_C + (t-1)E_E} \times 100 \text{ .....Eq. 5}$$

$$RE \text{ (LSD, column)} = \frac{(t)E_E}{E_C + (t-1)E_E} \times 100 \text{ .....Eq. 6}$$

The relative efficiency needs to be multiplied by the adjustment factor k when the error degrees of freedom in latin square analysis of variance is less than 20 (Gomez *et al.*, 1984) [2]. The empirical value of k can be obtained through the following expression:

$$k = \frac{[(t-1)(t-2)+1][(t-1)^3+3]}{[(t-1)(t-2)+3][(t-1)^3+1]} \text{ .....Eq. 7}$$

The crop varieties GJG 32 and GJG 19 were sown with a spacing of 45 cm x 10 cm and 45 cm x 15 cm, respectively. A block of 28 m x 15 m was harvested in contiguous unit of 0.90 m x 1.0 m consisting of 2 rows of 1 m each for 450 basic units. There were 60 rows each of 15 m length, making 450 basic units at all. The data on groundnut pod yield were recorded separately for the individual basic units. The various sized plots were formed by combining adjacent units and coefficient of variation in per cent for each size were calculated for pod yield.

## 2.2 Methodology

### 2.2.1 Relative efficiency of designs

The relative efficiency of simple, triple and balanced lattice designs relative to RCBD was estimated by superimposing each of these designs on the uniformity trial data and comparing their error variances following the procedure given by Robinson *et al.* (1948) [7]. Similarly, latin square design was compared with the RCBD and CRD.

The analysis of variance appropriate to uniformity trial data for lattice design (Zuhlke *et al.*, 1970) [8] is as under:

$$\text{Balanced lattice} = E_E \left[ 1 + \left( \frac{E_B - E_E}{E_B + E_E} \right) \right] \text{ .....Eq. 3}$$

Where E<sub>B</sub>, E<sub>E</sub> and k are same as mentioned above.

The error mean square of RCBD is estimated by adding the intrablock and interblock sum of squares and dividing it by their pooled degrees of freedom.

The relative efficiency of lattice design is calculated by dividing the error mean square of the RCBD by the effective error mean square of the lattice design and multiplying it by 100 to convert the result into per cent.

The analysis of variance for the uniformity trial data (Zuhlke *et al.*, 1970) [8] for latin square design parallel to the lattice design is given as below:

## 3. Results and Discussion

Considering the situation of Central Experimental Research Station (Sagadividi Farm), J.A.U., Junagadh., completely randomized design (CRD), randomized complete block design (RCBD), latin square design (LSD), simple, triple and balanced lattice designs were compared for their relative efficiencies using uniformity trial data on pod yield of groundnut varieties GJG-32 (Table 1) and GJG-19 (Table 2). The relative efficiency of LSD was compared with CRD and RCBD. The relative efficiency of simple, triple and balanced designs were compared with RCBD.

Table 1 presented the relative efficiency of different experimental designs for genotype GJG-32 at block sizes 4 and 5. At block size 4, the relative efficiency of LSD in relation to CRD (94.38 per cent) and RCBD row (96.99 per cent) and column blocks (96.21 per cent) was lower than unity, indicating inferior precision compared to RCBD.

However, incomplete block designs showed superior performance, particularly the balanced lattice design, which recorded the highest relative efficiency (106.30 per cent), followed by triple lattice (99.98 per cent) and simple lattice (97.06 per cent). This indicates that ac

counting for intra-block heterogeneity through balanced lattice arrangement substantially improved experimental precision.

At block size 5, improvements in efficiency were more pronounced. The balanced lattice design again exhibited the highest efficiency (111.09 per cent), followed by triple lattice (101.45 per cent) and LSD with column blocks (103.14 per cent). The relative efficiency of LSD over RCBD ranged from 98.51 per cent to 103.14 per cent, indicating only marginal gains. These results suggested that balanced lattice design consistently outperformed both complete and row-column designs, especially as block size increased.

The superiority of lattice designs over RCBD under heterogeneous field conditions aligns with the findings of Lin *et al.* (1993) [4], who concluded that lattice designs are more precise than RCBD when within-block variability is non-homogeneous. Similarly, Cochran

(1941) [1] reported substantial gains in accuracy (up to 15 per cent) with lattice square designs, emphasizing their advantage when plot heterogeneity exists.

Table 2 summarizes the relative efficiency of experimental designs for variety GJG-19. At block size 4, all incomplete block designs exhibited markedly higher relative efficiency than RCBD. The simple lattice design recorded the highest efficiency (120.67 per cent), followed by triple lattice (112.02 per cent) and balanced lattice (111.03 per cent). In contrast, the efficiency of LSD relative to CRD (114.08 per cent) was higher, but its efficiency relative to RCBD row (109.60 per cent) and column blocks (104.54 per cent) indicated only moderate improvement. These results demonstrate that incomplete block designs were substantially more effective in reducing experimental error for GJG-19 at smaller block sizes.

**Table 1.** Relative efficiency of experimental designs for GJG-32

| Block Size | LSD in relation to |           |              | Simple lattice in relation to RCBD | Triple lattice in relation to RCBD | Balanced lattice in relation to RCBD |
|------------|--------------------|-----------|--------------|------------------------------------|------------------------------------|--------------------------------------|
|            | CRD                | RCBD      |              |                                    |                                    |                                      |
|            |                    | Row block | Column block |                                    |                                    |                                      |
| 4          | 94.38              | 96.99     | 96.21        | 97.06                              | 99.98                              | 106.30                               |
| 5          | 101.59             | 98.51     | 103.14       | 99.99                              | 101.45                             | 111.09                               |

**Table 2.** Relative efficiency of experimental designs for GJG-19

| Block Size | LSD in relation to |           |              | Simple lattice in relation to RCBD | Triple lattice in relation to RCBD | Balanced lattice in relation to RCBD |
|------------|--------------------|-----------|--------------|------------------------------------|------------------------------------|--------------------------------------|
|            | CRD                | RCBD      |              |                                    |                                    |                                      |
|            |                    | Row block | Column block |                                    |                                    |                                      |
| 4          | 114.08             | 109.60    | 104.54       | 120.67                             | 112.02                             | 111.03                               |
| 5          | 99.05              | 98.72     | 100.29       | 100.10                             | 100.12                             | 104.34                               |

At block size 5, efficiencies of most designs approached unity. Balanced lattice (104.34 per cent) remained superior, whereas simple and triple lattice designs showed only marginal gains over RCBD (100.10 per cent and 100.12 per cent, respectively). The diminishing advantage at higher block size suggests improved homogeneity within blocks, reducing the relative benefit of lattice adjustments.

These findings corroborate the conclusions of Lantin *et al.* (1976) [3], who reported only modest gains (1.05-1.09) in efficiency of LSD over RCBD and emphasized the greater flexibility of RCBD when block homogeneity improves. However, under heterogeneous conditions and larger treatment numbers, lattice and alpha lattice designs provide superior precision, as demonstrated by Masood *et al.* (2008) [5] and Raza *et al.* (2009) [6], who reported efficiency gains ranging from 17 per cent to 55 per cent over RCBD.

Overall, the balanced lattice design emerged as the most superior experimental design. It consistently recorded the highest relative efficiency over RCBD across both groundnut varieties (GJG-32 and GJG-19) and block sizes (4 and 5). This indicates its better ability to control field variability and improve experimental precision. The advantage of the balanced lattice design was more pronounced at smaller block sizes. In comparison, LSD and other lattice designs showed only marginal or inconsistent gains over RCBD. Hence, the balanced lattice design is most suitable for experiments involving a large number of treatments under heterogeneous field conditions.

## 4. Practical implications for groundnut experimentation

The results have several implications for planning field experiments on groundnut.

### 4.1 Importance of field heterogeneity

The principal purpose of using incomplete block designs is to obtain better control of local variability. The results indicate that their usefulness can be substantial when the experimental area contains spatial heterogeneity.

### 4.2 Importance of the number of treatments

Lattice designs become particularly relevant when a large number of treatments or genotypes are included in a trial. Dividing a large replication into smaller incomplete blocks can provide additional control over local variation.

### 4.3 Block size should be selected carefully

The results obtained from GJG-32 and GJG-19 demonstrate that changing block size can alter relative efficiency. Therefore, block size should not be selected solely on the basis of a general rule.

### 4.4 Balanced lattice showed consistently high efficiency

Balanced lattice produced relative efficiency values above 100 per cent for both varieties and both block sizes:

- GJG-32, block size 4: **106.30%**
- GJG-32, block size 5: **111.09%**
- GJG-19, block size 4: **111.03%**
- GJG-19, block size 5: **104.34%**

Thus, balanced lattice demonstrated a consistent efficiency advantage relative to RCBD within the evaluated uniformity-trial conditions.

## 5. Conclusion

The relative efficiency of six experimental design structures was evaluated using uniformity trial data for two groundnut varieties, GJG-32 and GJG-19, at the Central Experimental Research Station (Sagadividi Farm), Junagadh Agricultural University, Junagadh. The results demonstrated substantial variation in design efficiency according to groundnut variety and block size. For GJG-32, balanced lattice produced relative efficiencies of 106.30 and 111.09 per cent at block sizes 4 and 5, respectively. For GJG-19, the corresponding values were 111.03 and 104.34 per cent. Overall, the study demonstrates that incomplete block designs – lattice designs can provide improved experimental precision over RCBD when the field contains relevant spa

tial heterogeneity. Balanced lattice showed a consistently high efficiency across the two varieties and both block sizes evaluated.

## References

1. Cochran WG. An examination of the accuracy of lattice and lattice square experiments on corn. Iowa Agricultural Experiment Station Research Bulletin. 1941;289:400-415.
2. Gomez AK, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley and Sons; 1984.
3. Lantin MM, Empig LT. Comparative efficiency of experimental designs used in sugarcane variety tests. Philippine Journal of Crop Science. 1976;1(2):87-90.
4. Lin CS, Binns MR, Voldeng HD, Guillemette R. Performance of randomized block designs in field experiments. Agronomy Journal. 1993;85:168-171.
5. Masood MA, Malik SN, Nazakat N. The blocks within replication improve experimental efficiency in preliminary yield trial on groundnut. Pakistan Journal of Agricultural Research. 2008;20(3,4):116-118.
6. Raza I, Masood MA. Efficiency of Lattice design in relation to Randomized Complete Block Design in agricultural field experiments. Pakistan Journal of Agricultural Research. 2009;22(3-4):150-153.
7. Robinson JF, Rigney JA, Harvey PH. Investigations in plot technique with peanuts. North Carolina Agricultural Statistical Technical Bulletin. 1948;86:20.
8. Zuhlke TA, Gritton ET. Relative precision of different experimental designs and number of replications in pea yield trials. Agronomy Journal. 1970;62:61-64.

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