

## Relative Efficiency of Latin Square Design on Natural Grasslands in Chambal Ravines of Southeastern Rajasthan

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**Abstract:** The efficiency of various Latin Square Designs (LSD) over Complete Randomized Designs (CRD) and Randomized Complete Block Designs (RCBD) in natural grasslands of Chambal ravines in southeastern Rajasthan, were worked out. The relative efficiency percentage of 3x3, 4x4, 5x5 and 6x6 LSD for different plot sizes and shapes were comparable to CRD and RCBD when rows were treated as blocks (ignoring columns), and when columns were treated as blocks (ignoring rows). The number of units required in CRD and RCBD, taking rows as blocks or columns as blocks, for obtaining the relative efficiency (RE) equivalent to that of 3x3 to 6x6 LSD, were also evaluated. It was found that LSD was more efficient than CRD and RCBD for experimentation in natural grasslands of Chambal ravine in southeastern Rajasthan.

**Key words:** Natural grassland, relative efficiency, complete randomized design, randomized complete block design, Latin Square Design.

The Latin Square Design (LSD) is one of the most important designs used in agricultural experimentation (Cochran and Cox, 1957; Kempthorne, 1952; Federer, 1955). It provides more opportunity than Complete Randomized Design (CRD) and Randomized Complete Block Design (RCBD) for the reduction of experimental error by skilful planning. The LSD is generally laid out when there is no information on the direction of fertility variation, or when simultaneous control of variation in two directions is desired. The advantages of the LSD over CRD and RCBD, from the point of view of increasing precision, can be measured by the "relative efficiency", which is directly related to the proportional reduction in the error variance or to the equivalent reduction in the number of experimental units needed

to attain a given precision (Abou-el-Fittouh, 1977).

The relative efficiency of LSD over CRD and RCBD for various sizes and shapes of plots have been studied for natural grasslands in southern India (Ram Babu *et al.*, 1996a), for natural grasses in Bundelkhand region (Sreenath *et al.*, 1991), and for natural grasslands in Agra ravines (Ram Babu *et al.*, 1996b). As no information is available for southeastern Rajasthan, the present study was undertaken to find out the relative efficiency of various LSD over CRD and RCBD, for various sizes and shapes of plots in natural grassland of Chambal ravines in southeastern Rajasthan. The methodology was adopted from Abou-el-Fittouh (1977).

## Materials and Methods

Grass yield data, in the units of 1 x 1 m (rows towards northeast-southwest and columns towards northwest-southeast), from the uniformity trial conducted on natural grasslands in plots of 24 x 24 m during 1996 at the CSWCRT Institute, Research Center Kota (longitude 75°52'18" to 75°52'44"E, latitude 25°13'29" to 25°14'18"N; 256.9 m above msl), were utilized (Agarwal *et al.*, 1998).

The relative efficiency of LSD, as compared to that of CRD and RCBD, were calculated as given by Kempthorne (1952) and expressed as suggested by Abou-el-Fittouh (1977). The RE of LSD compared with the CRD may be expressed as:

$$RE(\%) = A + BF_1 \quad \dots(1)$$

where,

$A = 100p(r-1)/(r+1)$ ,  $B = 100p/(r+1)$  and  $F_1 = F_r + F_c$ . Here,  $F_r$  and  $F_c$  are the calculated F-values for rows and columns, respectively, and the precision factor (Steel and Torrie, 1960),

$$P = \frac{(n_1 + 1)(n_2 + 3)}{(n_2 + 1)(n_1 + 3)}$$

where,

$n_1$  and  $n_2$  are the error degrees of freedom in LSD and CRD, respectively, and are

used to adjust the differences in the error degrees of freedom in the two designs.

Similarly, the RE compared with RCBD may be expressed as:

$$RE(\%) = A + BF_2 \quad \dots(2)$$

where,

$A = 100p(r-1) / r$ ,  $B = 100p / r$  and  $F_2 = F_r$  when calculating the efficiency relative to RCBD with columns as blocks (i.e., rows are ignored), and  $F_2 = F_c$  when columns are ignored and the rows are considered as blocks. In equation (2)  $n_1$  is as defined earlier when  $n_2$  is  $(r-1)^2$ , the error degrees of freedom in RCBD. Approximate number of units required in CRD and RCBD equivalent to units in LSD were worked out by the formula  $RE(\%) \times r^2/100$ , where  $r$  is the size of Latin Square under study.

## Results and Discussion

The constants A and B in equations (1) and (2) were evaluated to give the following set of linear expressions for estimating the relative efficiency of the LSD (Table 1).

Each of the above expressions was graphically presented for values of  $F_1$  and  $F_2$ , ranging from 0 to 12 for efficiency relative to CRD and RCBD, respectively (Figs. 1 and 2). Relative percentage efficiency of LSD (3x3, 4x4, 5x5 and 6x6)

Table 1. Values of the constants A and B for estimating RE of LSD

Latin Square size	Efficiency relative to	
	CRD	RCBD
3 x 3	38.571 + 19.296F <sub>1</sub>	56.000 + 28.000F <sub>2</sub>
4 x 4	53.846 + 17.949F <sub>1</sub>	70.000 + 23.333F <sub>2</sub>
5 x 5	63.280 + 15.820F <sub>1</sub>	77.490 + 19.373F <sub>2</sub>
6 x 6	69.425 + 13.885F <sub>1</sub>	81.940 + 16.388F <sub>2</sub>

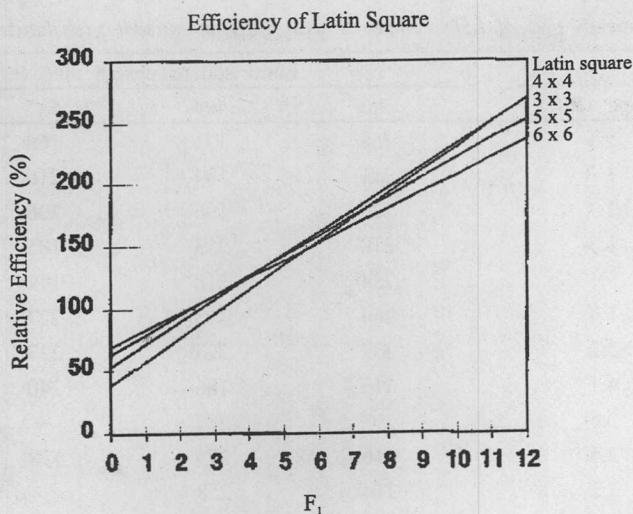


Fig. 1. Relation between  $F_1$  and RE in case of CRD.

over CRD for various plot sizes and shapes were calculated. For 3x3 and 6x6 Latin Square, it ranged from 139 to 547, 171 to 416, 168 to 251 and 130 to 282 (Table 2), whereas in comparison with RCBD, considering rows as blocks (ignoring columns), relative efficiency ranged from 143 to 600, 154 to 329, 128 to 235 and 148 to 236. When columns were treated

as blocks (ignoring rows), it ranged from 131 to 625, 109 to 294, 124 to 266 and 129 to 277 (Table 3). Further, it was observed that the plot shape had no consistent effect on the efficiency of LSD. The efficiencies of LSD were higher in comparison to RCBD, taking columns as blocks (ignoring rows), than considering rows as blocks (ignoring columns).

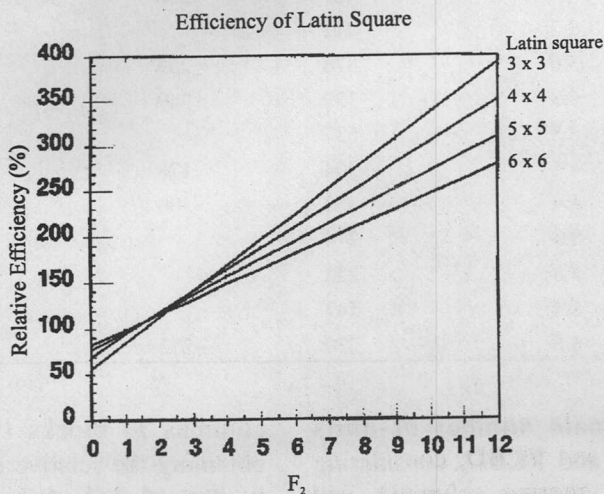


Fig. 2. Relation between  $F_2$  and RE in case of RCBD.

Table 2. Relative efficiency (%) of LSD compared with CRD in natural grasslands of Chambal ravines

Plot		Latin square design size (r x r)			
Size (sq. m)	Shape (R:C)	3x3	4x4	5x5	6x6
1	1:1	168	171	168	171
2	1:2	211	184	210	222
2	2:1	223	196	206	196
3*	1:3	210	253	185	202
3	3:1	234	218	199	186
4	1:4	264	213	227	217
4	2:2	339	223	237	232
4	4:1	313	186	240	238
6	1:6	217	262		
6	2:3	416	275	178	189
6	3:2	214	258		
6	6:1	272	239	194	210
8	1:8	340	-		
8	2:4	366	272	218	203
8	4:2	322	180	251	282
8	8:1	521			
9	3:3	233	285	170	178
12	2:6	208	250		
12	3:4	439	416	184	212
12	4:3	283	231	199	130
12	6:2	167	233		
16	2:8	258			
16	4:4	483	228	215	241
16	8:2	412			
18	3:6	376	259		
18	6:3	139	249		
24	3:8	537			
24	4:6	304	178		
24	6:4	352	300		
24	8:3	274			
32	4:8	223			
32	8:4	547			
32	6:6	230	272		

The approximate number of units required in CRD and RCBD, considering rows as blocks (ignoring columns), and

columns as blocks (ignoring rows), for obtaining the relative efficiency equivalent to that of 3x3, 4x4, 5x5 and 6x6 LSD,

Table 3. Relative efficiency (%) of LSD compared with RCBD in natural grasslands of Chambal ravines

Plot		Latin Square Design size (r x r)							
Size (sq. m)	Shape (R:C)	3x3		4x4		5x5		6x6	
		R	C	R	C	R	C	R	C
1	1:1	154	191	154	181	146	171	148	175
2	1:2	196	235	173	188	179	210	184	213
2	2:1	226	252	183	212	192	207	164	206
3	1:3	211	215	223	258	166	157	189	147
3	3:1	236	263	195	237	166	204	156	195
4	1:4	235	296	210	174	193	168	187	163
4	2:2	341	364	217	221	231	235	192	224
4	4:1	266	361	164	199	200	249	195	256
6	1:6	229	162	245	188				
6	2:3	438	387	266	280	186	142	174	130
6	3:2	235	241	229	256	165	211	172	213
6	6:1	216	317	216	267				
8	1:8	309	260						
8	2:4	373	393	275	185	235	124	189	131
8	4:2	291	381	169	177	222	266	236	277
8	8:1	478	621						
9	3:3	269	228	248	294	128	157	163	129
12	2:6	245	131	263	140				
12	3:4	484	503	329	273	170	132	191	141
12	4:3	253	296	196	260	161	160	204	149
12	6:2	151	205	226	239				
16	2:8	290	155						
16	4:4	426	528	199	165	210	129	224	142
16	8:2	410	497						
18	3:6	451	203	257	142				
18	6:3	143	157	239	265				
24	3:8	600	302						
24	4:6	294	177	190	109				
24	6:4	310	421	267	189				
24	8:3	287	299						
32	4:8	221	141						
32	8:4	551	625						
36	6:6	242	142	293	128				

R = Rows as blocks (ignoring columns); C = Columns as blocks (ignoring rows).

were worked out. In CRD, it ranged from 13 to 49, 27 to 67, 42 to 63 and 62 to 102. In RCBD, taking rows as blocks, it varied from 13 to 54, 25 to 53, 32 to 59 and 53 to 85, while taking columns as blocks, it ranged from 12 to 56, 18 to 47, 31 to 66 and 46 to 100, respectively.

Table 4. Number of units required in CRD and RCBD equivalent to units in LSD in natural grasslands of Chambal ravines

Plot		3 x 3			4 x 4			5 x 5			6 x 6		
Size (sq. m)	Shape (R:C)	CRD	RCBD		CRD	RCBD		CRD	RCBD		CRD	RCBD	
			R	C		R	C		R	C		R	C
1	1:1	15	14(5)	17(6)	27	25(6)	29(7)	42	37(7)	43(9)	62	53(9)	63(10)
2	1:2	19	18(6)	21(7)	30	28(7)	30(8)	52	45(9)	52(10)	80	66(11)	77(13)
2	2:1	20	29(7)	23(8)	31	29(7)	34(8)	51	48(10)	52(10)	71	59(10)	74(12)
3	1:3	19	19(6)	19(6)	40	36(9)	41(10)	46	41(8)	39(8)	73	68(11)	53(9)
3	3:1	21	21(7)	24(8)	35	31(8)	38(9)	50	42(8)	51(10)	67	56(9)	70(12)
4	1:4	24	21(7)	27(9)	34	34(8)	28(7)	57	48(10)	42(80)	68	67(11)	59(10)
4	2:2	31	31(10)	33(11)	36	35(9)	35(9)	59	58(12)	59(12)	83	69(12)	81(13)
4	4:1	28	24(8)	33(11)	30	26(7)	32(8)	60	50(10)	62(12)	86	70(12)	92(15)
6	1:6	19	21(7)	15(5)	42	39(10)	30(8)						
6	2:3	37	39(13)	35(12)	44	43(11)	45(11)	45	47(9)	35(7)	68	63(10)	47(8)
6	3:2	19	21(7)	22(7)	41	37(9)	41(10)	49	41(8)	53(11)	75	62(10)	77(13)
6	6:1	25	19(6)	29(10)	38	35(9)	43(11)						
8	1:8	31	28(9)	23(8)									
8	2:4	33	34(11)	35(12)	44	44(11)	30(7)	55	59(12)	31(6)	73	68(11)	47(8)
8	4:2	29	26(9)	24(11)	29	27(7)	28(7)	63	55(11)	66(13)	102	85(14)	100(17)
8	8:1	47	43(14)	56(19)									
9	3:3	21	24(8)	21(7)	46	40(10)	47(12)	42	32(6)	39(8)	64	59(10)	46(8)
12	2:6	19	22(7)	12(4)	40	42(11)	22(6)						
12	3:4	40	44(15)	45(15)	67	53(13)	44(11)	46	42(8)	33(7)	76	69(11)	51(8)
12	4:3	25	23(8)	27(9)	37	31(8)	42(10)	50	40(8)	40(8)	83	73(12)	54(9)
12	6:2	15	14(5)	18(6)	37	36(9)	38(10)						
16	2:8	23	26(9)	14(5)									
16	4:4	43	38(13)	47(16)	37	32(8)	27(7)	54	53(11)	32(6)	87	81(13)	51(9)
16	8:2	47	37(12)	45(15)									
18	3:6	34	41(14)	18(6)	41	41(10)	23(6)						
18	6:3	13	13(4)	14(5)	40	38(10)	42(11)						
24	3:8	48	54(18)	27(9)									
24	4:6	27	26(9)	16(5)	28	30(8)	18(4)						
24	6:4	32	28(9)	38(13)	48	43(11)	30(8)						
24	8:3	25	26(9)	27(9)									
32	4:8	20	20(7)	13(4)									
32	8:4	49	50(17)	56(19)									
36	6:6	21	22(7)	13(4)	44	47(12)	20(5)						

It is inferred that the LSD is more efficient than CRD and RCBD, either taking rows as blocks (ignoring columns), or columns as blocks (ignoring rows), for

experimentation in natural grasslands in Chambal ravines of southeastern Rajasthan.

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