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Relative Efficiency of Latin Square Design on Natural Grasslands in Agra Ravines

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Abstract : The efficiency of various Latin Square Designs (LSD) relative to the Complete Randomised Designs (CRD) and Randomised Complete Block Designs (RCBD) for various sizes and shapes of plots on natural grasslands of Agra ravines was worked out. The relative efficiencies (percentage) of 3x3, 4x4, 5x5 and 6x6 LSD for different plot sizes and shapes were compared with CRD and RCBD, when rows were treated as blocks (ignoring columns) and when columns were treated as blocks (ignoring rows) have been computed. The number of units required in CRD and RCBD taking rows as blocks or columns as blocks for obtaining the relative efficiency equivalent to that of 3x3 to 6x6 LSD were also evaluated and it was found that LSD was more efficient than CRD and RCBD for experimentation with natural grasslands having more than 10% slope.

Key words : Natural grassland, relative efficiency, complete randomised design, randomised complete block design, latin square design.

The latin square, one of the most important designs used in agricultural experimentation, is described in detail by Cochran and Cox (1957), Kempthorne (1952) and Federer (1955). The LSD provides more opportunity than CRD and RCBD for the reduction of experimental error by skillful planning. The latin square design is generally laid out when there is no information of 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 "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 potato crop in the hills (Malhotra *et al.*, 1979) and for natural grasses in Bundelkhand region (Sreenath *et al.*, 1991). As no information is available for ravine areas having more than 10% slope, present study were aimed to find out the relative efficiency of LSD over CRD and RCBD for various sizes and shapes of plots in natural grasslands at Agra ravines. The analysis methodology was undertaken followig Abou-El-Fittouh (1977).

Materials and Methods

Average yield data of two consecutive years in units of 1m x 1m (rows along the slope and columns across the slope) from a uniformity trial conducted on natural grasslands on plots of 24m x 24m having more than 10% slope along the row side at the Research Centre, Agra (longitude 78°21'E, latitude 27°10'N, elevation 169 m above MSL) were utilized (Ram Babu *et al.*, 1981).

Table 1. Relative efficiency (%) of LSD compared with CRD in natural grasslands having 10% slope

Plot		Latin square design size (r x r)			
Size (m^2)	Shape	3 x 3	4 x 4	5 x 5	6 x 6
1	1:1	269	252	256	261
2	1:2	416	334	317	317
2	2:1	385	292	318	324
3	1:3	739	470	297	419
3	3:1	441	351	243	337
4	1:4	696	398	489	387
4	2:2	404	289	363	261
4	4:1	597	349	387	353
6	1:6	1200	471	–	–
6	2:3	403	327	175	306
6	3:2	660	340	249	289
6	6:1	379	340	–	–
8	1:8	665	–	–	–
8	2:4	508	334	338	316
8	4:2	626	475	350	358
8	8:1	457	–	–	–
9	3:3	415	275	169	402
12	2:6	458	247	–	–
12	3:4	462	240	456	444
12	4:3	319	310	324	472
12	6:2	601	464	–	–
16	2:8	496	–	–	–
16	4:4	315	559	1098	487
16	8:2	729	–	–	–
18	3:6	223	327	–	–
18	6:3	408	361	–	–
24	3:8	256	–	–	–
24	4:6	386	543	–	–
24	6:4	412	676	–	–
24	8:3	808	–	–	–
32	4:8	294	–	–	–
32	8:4	622	–	–	–

The relative efficiency of LSD compared with the CRD and RCBD are given by Kempthorne (1952) as follows :

a) Efficiency relative to CRD;

$$RE = [R+C+(r-1)E]/(r+1)E \quad ....(1)$$

b) Efficiency relative to RCBD with rows as blocks;

$$RE = [C+(r-1)E]/rE \quad ....(2)$$

c) Efficiency relative to RCBD with columns as blocks;

$$R = [R+(r-1)E]/rE \quad ....(3)$$

Table 2. Relative efficiency (%) of LSD compared with RCBD in natural grasslands having 10% slope

Plot Size (m^2)	Plot Shape* (R:C)	Latin square design size (r x r) 3 x 3 R	3 x 3 C	4 x 4 R	4 x 4 C	5 x 5 R	5 x 5 C	6 x 6 R	6 x 6 C
1	1:1	319	286	284	258	279	240	271	254
2	1:2	503	462	384	308	356	242	342	309
3	2:1	432	422	297	316	328	306	311	328
3	1:3	919	547	554	478	334	128	453	188
3	3:1	448	509	359	380	230	250	278	353
4	1:4	863	745	478	224	568	153	436	178
4	2:2	462	472	306	287	389	281	275	283
4	4:1	625	673	314	394	363	384	280	375
6	1:6	1518	459	575	203	–	–	–	–
6	2:3	480	331	354	368	194	105	316	164
6	3:2	683	763	361	334	246	220	263	304
6	6:1	348	459	295	389	–	–	–	–
8	1:8	846	317	–	–	–	–	–	–
8	2:4	611	585	366	207	390	129	354	164
8	4:2	677	761	422	483	348	290	300	394
8	8:1	437	546	–	–	–	–	–	–
9	3:3	474	277	314	326	166	119	411	145
12	2:6	557	212	295	140	–	–	–	–
12	3:4	520	524	252	164	480	157	424	182
12	4:3	353	279	300	359	329	145	417	222
12	6:2	550	731	398	460	–	–	–	–
16	2:8	633	256	–	–	–	–	–	–
16	4:4	382	398	543	255	1140	282	429	228
16	8:2	700	906	–	–	–	–	–	–
18	3:6	283	98	398	169	–	–	–	–
18	6:3	462	267	330	435	–	–	–	–
24	3:8	321	135	–	–	–	–	–	–
24	4:6	458	199	567	208	–	–	–	–
24	6:4	417	517	600	349	–	–	–	–
24	8:3	800	669	–	–	–	–	–	–
32	4:8	379	185	–	–	–	–	–	–
32	8:4	635	808	–	–	–	–	–	–

* R is rows as blocks (ignoring columns) and C is column as blocks (ignoring rows).

where,

R is row mean square, C is column mean square;
E is error mean square, and r is number of treatments

Equation (1) may be expressed as :

$$RE = (F_r + F_c)/(r+1) + (r-1)/(r+1) \quad ..(4)$$

where,

F_r and F_c are the calculated F-values for rows and columns, re-

Table 3. Number of units required in CRD and RCBD equivalent to units in LSD in natural grasslands

Plot Size (m^2)	Plot Shape* (R:C)	Latin square design size (r x r) 3 x 3 CRD	3 x 3 RCBD R	3 x 3 RCBD C	4 x 4 CRD	4 x 4 RCBD R	4 x 4 RCBD C	5 x 5 CRD	5 x 5 RCBD R	5 x 5 RCBD C	6 x 6 CRD	6 x 6 RCBD R	6 x 6 RCBD C
1	1:1	24	29(10)	26(9)	40	45(1)	41(10)	64	70(19)	60(12)	947	98(16)	91(15)
2	1:2	37	45(15)	42(14)	53	62(15)	49(12)	79	89(18)	61(12)	114	123(21)	111(19)
3	2:1	35	39(13)	38(13)	47	48(12)	51(13)	79	82(16)	76(15)	117	112(19)	118(20)
3	1:3	66	83(28)	49(16)	75	89(22)	76(19)	74	83(17)	32(6)	151	163(27)	68(11)
3	3:1	40	40(13)	46(15)	56	58(14)	61(15)	61	57(11)	62(12)	121	100(17)	127(21)
4	1:4	63	78(26)	67(22)	64	76(19)	36(9)	122	142(28)	38(8)	139	157(26)	64(11)
4	2:2	36	42(14)	43(14)	46	49(12)	46(11)	91	97(19)	70(14)	94	99(17)	102(17)
4	4:1	54	56(19)	61(20)	56	50(13)	63(16)	97	91(18)	96(19)	127	101(17)	135(23)
6	1:6	108	137(46)	41(14)	75	92(23)	32(8)	–	–	–	–	–	–
6	2:3	36	43(14)	30(10)	52	57(14)	59(15)	44	49(10)	26(5)	110	114(19)	59(10)
6	3:2	59	61(20)	69(23)	54	58(14)	54(13)	62	62(12)	55(11)	104	95(16)	109(18)
6	6:1	34	31(10)	41(14)	54	47(12)	62(16)	–	–	–	–	–	–
8	1:8	60	76(25)	29(10)	–	–	–	–	–	–	–	–	–
8	2:4	46	55(18)	53(18)	53	59(15)	33(8)	85	97(19)	32(6)	114	128(21)	59(10)
8	4:2	56	61(20)	68(23)	76	68(17)	77(19)	87	87(17)	72(14)	129	108(18)	142(24)
8	8:1	41	39(13)	49(16)	–	–	–	–	–	–	–	–	–
9	3:3	37	43(14)	25(8)	44	50(13)	52(13)	42	41(8)	30(6)	145	148(25)	52(9)
12	2:6	41	50(17)	19(6)	39	47(12)	22(6)	–	–	–	–	–	–
12	3:4	42	47(16)	47(16)	38	40(10)	26(7)	114	120(24)	39(8)	160	153(25)	65(11)
12	4:3	29	32(11)	25(8)	50	48(12)	57(14)	81	82(16)	36(7)	170	150(25)	80(13)
12	6:2	54	49(16)	66(22)	74	64(16)	74(18)	–	–	–	–	–	–
16	2:8	45	57(19)	23(8)	–	–	–	–	–	–	–	–	–
16	4:4	28	34(11)	36(12)	90	87(22)	41(10)	275	285(57)	71(14)	175	154(26)	82(14)
16	8:2	66	63(21)	82(27)	–	–	–	–	–	–	–	–	–
18	3:6	20	26(9)	9(3)	52	64(16)	27(7)	–	–	–	–	–	–
18	6:3	37	42(14)	24(8)	58	53(13)	70(17)	–	–	–	–	–	–
24	3:8	23	29(10)	12(4)	–	–	–	–	–	–	–	–	–
24	4:6	35	41(14)	18(6)	87	91(23)	33(8)	–	–	–	–	–	–
24	6:4	37	37(12)	47(16)	108	96(24)	56(14)	–	–	–	–	–	–
24	8:3	73	72(24)	60(20)	–	–	–	–	–	–	–	–	–
32	4:8	26	34(11)	17(6)	–	–	–	–	–	–	–	–	–
32	8:4	56	57(19)	73(24)	–	–	–	–	–	–	–	–	–

Figures within parentheses indicate approximate number of replications.
* R is rows as ablocks (ignoring columns) and C is column as blocks (ignoring rows).

spectively. To adjust for diferences in the error degrees of freedom in the two designs, the relative efficiency, as calculated by equation (4), should be multiplied by the following precision factor p (Steel and Torrie, 1960).

$$p = (n_1+1)(n_2+3)/(n_1+3)(n_2+1)$$

where,

n_1 and n_2 are the error degrees of freedom in LSD and CRD, respectively. Therefore, equation (4) becomes

$$RE\ (\%) = A + BF_1 \quad ....(5)$$

where,

$A = 100p(r-1)/(r+1)$, $B = 100p/(r+1)$ and $F_1 = F_r + F_c$

Similarly equations (2) and (3) may be expressed as

$$RE\ (\%) = A + BF_2 \quad ....(6)$$

where,

$RE\ (\%) = 100p(r-1)/r$, $B = 100p/r$

$F_2 = F_r$, when calculating the efficiency relative to RCBD with columns as blocks, and
$F_2 = Fc$, when columns are ignored and the rows are considered as blocks.

In (5) and (6), n_1 is defined earlier, while n_2 is 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 (%)*r*r/100, where, r*r is the type of latin square under study.

Results and Discussion

The relative efficiency expressed in terms of the linear functions expressed (equations 5 and 6), the efficiency (percentage) of LSD (3 x 3, 4 x 4, 5 x 5 and 6 x 6) over CRD for various size and shape of plots was calculated. It ranged from 223 to 1200, 240 to 676, 169 to 1098 and 261 to 487 for 3 x 3 to 6 x 6 latin squares (Table 1), whereas in comparison with RCBD considering rows as blocks (ignoring columns) it ranged from 283 to 1518, 252 to 600, 166 to 1140, 263 to 453 and ranged from 98 to 906, 140 to 483, 105 to 384, 145 to 394 when columns are treated as blocks (ignoring rows) (Table 2). The relative efficiency (%) in only 1 case of 3 x 3 LSD in comparison with RCBD considering columns as blocks (ignoring rows) was less efficient (Table 2). Comparison of RE for LSD with CRD for 3 x 3 and 5 x 5 gave very high values of 1200 and 1098, respectively. Similarly comparison with RCBD for 3 x 3 (R) and 5 x 5 sizes also gave high RE of 1518 and 1140, respectively. Such extremes are attributed to plot to plot variation in natural grasslands.

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 3 x 3, 4 x 4, 5 x 5 and 6 x 6 LSD were worked out. It ranged from 20 to 108, 38 to 108, 42 to 275 and 94 to 175 in CRD, where as, in RCBD, taking rows as blocks, varied from 26 to 137, 40 to 96, 41 to 285 and 95 to 163 while taking columns as blocks ranged from 9 to 82, 22 to 77, 26 to 96 and 52 to 142, respectively for ravine areas (Table 3).

The study suggests 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 having more than 10% slopes.

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