

# Latin Square Design (LSD)

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## Objective:

### To Analyze Latin Square Design (L.S.D.)

The following table gives the yields per plot of four treatments (A, B, C and D) after being applied to each of 4 plots, tested in a Latin Square Design. Analyze the data.

Row	Column				Total
	1	2	3	4	
1	120 (A)	115 (B)	130 (C)	125 (D)	490 =R <sub>1</sub>
2	110 (B)	118 (C)	128 (D)	122 (A)	478 =R <sub>2</sub>
3	117 (C)	125 (D)	123 (A)	119 (B)	484 =R <sub>3</sub>
4	121 (D)	120 (A)	119 (B)	124 (C)	484 =R <sub>4</sub>
Total	468 = C <sub>1</sub>	478 = C <sub>2</sub>	500 = C <sub>3</sub>	490 = C <sub>4</sub>	1936 (GT)

## Solution

### Linear model -

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \varepsilon_{ijk} \quad ; \quad (i=j=k=1,2, \dots, n)$$

Where  $Y_{ijk}$  = Response of the  $j^{\text{th}}$  replication,  $i^{\text{th}}$  treatment and  $k^{\text{th}}$  column

$\mu$  = General mean effect

$\alpha_i$  =  $i^{\text{th}}$  treatment effect

$\beta_j$  =  $j^{\text{th}}$  row effect

$\gamma_k$  =  $k^{\text{th}}$  column effect

$\varepsilon_{ijk}$  = error effect with mean=0 and variance =  $\sigma^2$  [N(0,  $\sigma^2$ )]

## Hypothesis

$H_0$ : All varieties of wheat have equal effect on yield ( $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4$ )

$H_1$ : All  $\alpha_i$ 's are not equal

Here No. of Treatments (k) = No. of Rows (k) = No. of Columns (k) = 4

No of Observations =  $k^2 = 16$

Correction Factor (C.F.)

$$= \frac{GT^2}{n} = \frac{(1936)^2}{16} = 234256$$

Total Sum of Square (TSS)

$$= \sum_{i=1}^n \sum_{j=1}^n \sum_{k=1}^n y^2_{ijk} - C.F.$$

$$= (120^2 + 115^2 + \dots + 124^2) - 234256 = 368$$

$$\text{Sum Square due to row (SSR)} = \frac{(R^2_1 + R^2_2 + R^2_3 + R^2_4)}{k} - C.F.$$

$$= \frac{(490^2 + 484^2 + 484^2 + 48^2)}{4} - 234256$$

$$= 18$$

$$\text{Sum Square due to column (SSC)} = \frac{(C^2_1 + C^2_2 + C^2_3 + C^2_4)}{k} - C.F.$$

$$= \frac{(468^2 + 478^2 + 500^2 + 490^2)}{4} - 234256$$

$$= 146$$

	A	B	C	D
	120	110	117	121
	120	115	118	125
	123	119	130	128
	122	119	124	125
Total	T <sub>A</sub> = 485	T <sub>B</sub> = 463	T <sub>C</sub> = 489	T <sub>D</sub> = 499
Mean (Rounded)	$\bar{Y}_A = 121$	$\bar{Y}_B = 116$	$\bar{Y}_C = 122$	$\bar{Y}_D = 125$

Sum Square due to treatment

$$= \frac{(T^2_A + T^2_B + T^2_C + T^2_D)}{k} - C.F.$$

$$= \frac{(48^2 + 463^2 + 48^2 + 499^2)}{4} - 234256$$

$$= 173$$

Sum Square due to (SSE) = T.S.S. - SST - SSR - SSC

$$= 368 - (173 + 18 + 146)$$

$$= 31$$

ANOVA table

Source of variation	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F <sub>cal</sub>	F <sub>(3,6)</sub>	
					5%	1%
Treatments	k-1=3	173	57.7	11.16**	4.76	9.78
Rows	k-1=3	18	6.0			
Columns	k-1=3	146	48.7			
Error	(k-1)(k-2)=6	31	5.2			
Total	(k <sup>2</sup> -1)=15	368				

Since  $F_{cal} = 11.16 > F_{tab} = 9.78$ , Therefore null hypothesis  $H_0$  at (1%) level of significance with degree of freedom (3,6) will be rejected. Hence there is a highly significant difference between the treatments.

To test the treatmentt (pair wise) arranges means in descending order

$$\bar{Y}_D = 125, \bar{Y}_C = 122, \bar{Y}_A = 121, \bar{Y}_B = 116$$

$$SE(d) = \sqrt{EMS \left( \frac{1}{r_i} + \frac{1}{r_j} \right)} = \sqrt{Ve \left( \frac{1}{r_i} + \frac{1}{r_j} \right)} = \sqrt{5.2 \left( \frac{1}{4} + \frac{1}{4} \right)} = 1.61$$

$$\text{Critical Difference (C.D.)} = SE(d) \times t_{\text{error d.f. (5\%)}}$$

$$= 1.61 \times t_6 (5\%) = 0.41 \times 2.45 = 3.93$$

Treatment	Difference of treatment means	Compare with CD
D-C	3	
D-A	4	Significant
D-B	9	Significant
C-A	1	
C-B	6	Significant
A-B	5	Significant

$$\bar{y} = \frac{GT}{n} = \frac{1936}{16} = 121 ;$$

$$CV = \frac{\sqrt{MSE}}{\bar{y}} \times 100 = \frac{\sqrt{5.2}}{121} \times 100 = 1.9\%$$

**Conclusion:** - Treatment D gives significantly higher yield than all other treatments; but the remaining treatments are all on par.

**Exercise:**

An Experiment on cotton was conducted to study the effect of foliar application of urea in combination with insecticidal sprays in the cotton yield. Five treatments were tried in a 5×5 Latin Square Design. The layout and yield is given below.

T <sub>2</sub> 4.9	T <sub>4</sub> 6.4	T <sub>5</sub> 3.3	T <sub>1</sub> 9.5	T <sub>3</sub> 11.8
T <sub>3</sub> 9.3	T <sub>1</sub> 4.0	T <sub>2</sub> 6.2	T <sub>5</sub> 5.1	T <sub>4</sub> 5.4
T <sub>4</sub> 7.0	T <sub>3</sub> 15.4	T <sub>1</sub> 6.5	T <sub>2</sub> 6.0	T <sub>5</sub> 4.6
T <sub>5</sub> 5.3	T <sub>2</sub> 7.6	T <sub>3</sub> 13.2	T <sub>4</sub> 8.6	T <sub>1</sub> 4.9
T <sub>1</sub> 9.3	T <sub>5</sub> 6.3	T <sub>4</sub> 11.8	T <sub>3</sub> 15.9	T <sub>2</sub> 7.6

Analyze the data and state your conclusions.