Experiment Design:

In Experimental design, we use "Plan" to collect data relevent to problem to make valid & effective inference about the stated problem.

By "Plan" means:

→ Allocation of treatment, whose effects are to be studied in the relevant problem.

→ Allocation of experimental layout

→ And Collection of data

→ Objectives:

1- To get maximum information in minimum expenditure & time.

2- By using Exp. techiques, we can avoid Systematic errors

3- We can explain outcomes logically & critically

→ Basic Principles:

1- Randomization

2- Replication

3- Local Control

RANDOMIZATION

Randomization is the first principle.

In Randomization, "Every treatment has a same chance to be selected in Experimental Unit"

⇒ Treatment :

"It is a condition, whose effect to be studied in the problem."

⇒ Exp. unit:

"It is a smallest (unit)' division of Experimental (unit)' layout/material."

By using Randomization, we remove the Biaseness from the data.
Randomization is done by playing cards, lottery system, random number table and lucky draw.

REPLICATION

Replication is the second principle.
In Replication, "we repeat the basic experiment more than one time"

⇒ Basic experiment:

"It is a complete run of all the treatments."

As we know, All the experiments, individuals or plots are not similar in characteristics.
To avoid this error, by using Replication in a single use of basic experiment is called Replicate."

LOCAL CONTROL

It is observed that Randomization & Replication sometime failed to control the extraneous variation when there is need to refine an Experimental technique by introducing local Control. Local Control means "Balancing, Blocking and Grouping."

⇒ **Balancing:**

"The agreement between treatment & Exp. unit" (or)

"The agreement of allocation of the treatment between Experimental units."

⇒ **Blocking:**

"In blocking, the allocation of treatment in such a way that every replication should be in homogenous groups."

By using local control, we remove the variation from exp. unit, to get more and effective outcome.

K = Treatment = 4

R_1	A	B	C	D	Replications = 4
R_2	C	A	D	$\boxed{B}$	→ Experimental unit
R_3	B	B	C	A	
R_4	A				

- In CR-Design, Exp units combine to form Replications.
- But In RCBD-Designs, R = B. Replication refers to Block

Complete Randomized Desing or (CR)

→ It is the simplest type of Basic design.
→ It is based on Randomization.
→ "In CR-Design. Randomization is Un-restricted. which means, any number of treatment at any number of times can be used in any number of exp. units."
→ It is widely used in laboratory experiments. where we have homogenous material and some of the treaments are destroyable or fail to respond.

For weight gain	Dog Breed
diet - A	1
diet - B	2
diet - C	3

Diet Dog Breed

Replication (I) R-I
A → 1
B → 2
C → 3

R-II
A → 1
A → 2
C → 3

unconditional

R.I	A	B	C
R-II	A	A	C
R-III	A	B	B

R-III
A → 1
B → 2
B → 3

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STAT-402

Question no 1: (Related to CR-Design)

An experiment was conducted to compare the yield of 3 varieties of Potatoes. Each variety was assigned at random to equal size plot four times. The yield is as follow

Varieties

$A, B, C = 3 \rightarrow$ Treatment

	A	B	C
r_1	23	18	16
r_2	26	28	25
r_3	20	17	12
r_4	17	21	14
Total =	86	84	67

Grand Total = 237

Test the ~~to~~ hypothesis of 3 varieties of potatoes are not different in the Yielding capabilities?

Solution:-

1- Hypothesis:

$$H_0 = \mu_A = \mu_B = \mu_C$$

H_1 = Atleast one is different

or

$$H_1 \neq \mu_A \neq \mu_B \neq \mu_C$$

2- Level of Significance:

$$\alpha = 0.05$$

or 0.01

or 0.025

3. Test Statistics,

$$F = \frac{S^2_t}{S_e}$$

where S^2_t = mean square of treatment
S^2_e = mean square error
S^2 = variance

4. Computation:

$$CF = \frac{(G)^2}{n}$$

where. G = grand total
n = no. of values

$$CF = \frac{(G)^2}{n}$$

$$\text{Correct Factor} = \frac{(237)^2}{12}$$

$$= \frac{56169}{12}$$

$$\boxed{CF = 4680.15}$$

$$TSS = \Sigma\Sigma Y_{ij}^2 - CF$$

$$= 23)^2 + (26)^2 + (20)^2 + \ldots (14)^2 - 4680$$

$$= 4953 - 4680$$

$$\boxed{TSS = 272.25}$$

$$\text{Treat SS} = \frac{\Sigma T_i^2}{r} - CF \qquad \{\because r = \text{Replications}\}$$

$$= \frac{(86)^2+(84)^2+(67)^2}{4} - 11630$$

$$\boxed{\text{Treat SS} = 54.50}$$

$$ESS = TSS - \text{Treat SS}$$

$$= 272.50 - 54.50$$

$$\boxed{ESS = 217.75}$$

ANOVA TABLE (Analysis of Variance)

Source of Variance (SOV)	Degree of freedom (df)	Sum of Square (SS)	Mean Square (MS)	Formula (F)
Treatment	K-1 = ? 3-1 = 2	54.50	$SS/df = \frac{54.50}{2} = 27.25$	$\frac{27.25}{24.19} = 1.13$
Error	11-2 = 9	217.75	$SS/df = \frac{217}{9} = 24.19$	
Total	n-1 = ? 12-1 = 11	272.25		

5. Critical Region:

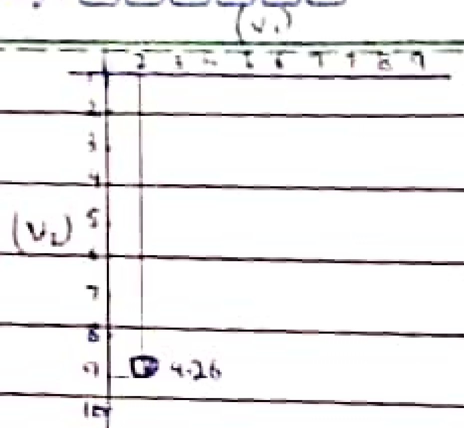
$$F \geq F_{\alpha,}(v_1, v_2) \qquad \{ v_1 = tdf = 2,\ v_2 = Edf = 9 \}$$

$$1.13 \geq F_{0.05}(2, 9)$$

F- distribution. level of significance

$$1.13 \geq = 4.26$$

$\alpha = 0.05$
$\alpha = 0.01$
$\alpha = 0.025$



6. Conclusion:

When the condition is false, Accept H_0 (or Type 1 error)

When the condition is true, Reject H_0

As all the calculated values falls in acceptance region, So we accept H_0. And conclude that All the varieties of potatoes have same yielding capacity at 5% level of Significance.

Experimental layout of CR. Design:

Let we have four treatments, A, B, C, D which are used in four Replications:

A	B	C	D
C	B	D	A
A	C	D	B
B	B	C	A

* Side Information:-

➔ Testing a hypothesis:

"A procedure which enable us whether to except or reject any statement or assumption about the population parameter, which may or may not be True"

Hypothesis may be: e.g → All diets have same effect

- Null hypothesis $(H^{\circ}) \rightarrow$ depends on Basic hypothesis
- Alternative hypothesis $(H_1) \rightarrow$ (~~depends~~) opposite to null hypothesis
  e.g All diets donot have same effect

μ = average

$$H_0 = \mu_A = \mu_B = \mu_C$$

$$H_1 = \mu_A \neq \mu_B \neq \mu$$

➔ Level of Significance:

"The probability of Rejecting H_0 when it ~~at~~ is infact True (H_0)"

Randomized Complete Block Design (RCBD)

→ In Randomized Complete Block Design (RCBD) we control one way variation by introducing Block in RCBD.
→ In RCBD, we devide the experimental material into relatively homogenous g Block
→ Homogenous Groups/Blocks means the assign material are relatively same.
→ Every block has a complete set of treatments, which is assigned by Randomization. And this randomization is restricted under the condition "Every Treatment appears single time in each replication. Every time a new randomization is made for every Block."

Experimental layout of RCBD:

+ **Numerical:**

4 Varieties of wheat were tried in Randomized Complete Block Design in 4 Replications. Yield in kg is shown:

	Varieties				
Replications	V_1	V_2	V_3	V_4	Total
R-I	2	5	4	1	12
R-II	2	3	3	1	9
R-III	4	6	6	2	18
R-IV	1	4	2	3	10
$\Sigma T =$	9	18	15	7	49

⇒ Grand Total (G

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Test the hypothesis that both varieties have same means.

Solution:-

1- Hypothesis:

$H_0 = \mu_A = \mu_B = \mu_c$

$H_1 \neq \mu_A \neq \mu_B \neq \mu_c$

H_1 atleast one is different

2- Level of Significance:

$\alpha = 0.01$

3- Test Statistics:

$$F = \frac{s^2 t}{s^2_e}$$

4. Computation:

$$C.F = \frac{G^2}{nk}$$

$$= \frac{(49)^2}{4 \times 4} = 150.06$$

$$TSS = \Sigma\Sigma Y_{ij}^2 - CF$$

$$= (2)^2 + (5)^2 + (4)^2 + (1)^2 + (2)^2 + (3)^2 + \dots (3)^2 - 150.06$$

$$= 191 - 150.06$$

$$= 40.9$$

$$\text{Treat SS} = \frac{\Sigma T_i^2}{n} - CF$$

$$= \frac{(9)^2 + (18)^2 + (15)^2 + (7)^2}{4} - 150.06$$

$$= 19.69$$

$$\text{Block SS or Replicate} = \frac{\Sigma B_i^2}{k} - CF$$

$$= \frac{(12)^2 + (9)^2 + (18)^2 + (10)^2}{4} - 150.06$$

$$= 12.19$$

Error SS = TSS - TreatSS - Block SS

$= 40.9 - 19.69 - 12.19$

$ESS = 9.06$

ANOVA TABLE

Sov	df $(k-1)$	SS	MS ss/df	Formula $F = \frac{S^2_t}{S^2_e}$
Treatment	$4-1=3$	19.69 ~~40.9~~	$19.6/3 = 6.56$	$F = 6.56/1.006$
Block	$4-1=3$	12.19	$12.9/3 = 4.06$	$F = 6.52$
Error	$3 \cdot 15 - 3 = 9$	9.06	$9.06/9 = 1.006$	
Total	$16-1=15$ $n-1$	40.94		

Comutation= 6.52

5. Critical Region:

$F \geq F_{\alpha}(v_1, v_2)$

$6.52 \geq F_{0.01}(3,9)$

$6.52 \geq 6.99$

6. Conclusion:

*(We accept Ho as condition is False.) As all the calculated values falls in acceptence region, so we conclude that all varieties of Wheat have same average. there is no difference in yielding capacity at level of significance of 0.01 or 1%.

1- Multiple Comparison Test

If F test, after the Anova table, rejects the null hypothesis (H_0) and then we conclude that the mean of K-treatments are not equal. It would not sufficient for the experimenth: (then) in this situation, we would like to find the significant (figures) pairs of K-treatment For this comparison, we use Multiple Comparison Test.

2- Least Significant difference Test (LSDT)

When the H_0 is rejects, after the Anova Table, their is need to find the significant pairs by comparing two treatments means $\bar{X}_i$ and $\bar{X}_j$, where $\bar{X}_i \neq \bar{X}_j$.

For each pair, we need $\frac{1}{2}k(k-1)$ by using (simple) two samples T-test. This procedure needs many decisions to overcome this difficulty, we ~~cand~~ calculate a least difference of the two treatment means, with comparing a smallest difference is given by

$$LSD = t_{\alpha/2}(edf)\sqrt{\frac{2MSE}{r}}$$ ∴ For equal no. of Replications

is called least Significant difference Test
Where MSE "MSE" is the Mean Square Error & "r" is the number of Replications, In equal sizes.
and $t_{\frac{\alpha}{2}}$ is the value for the t at α percent level of significance.

If the absolute difference of two treatment means exceeds the LSD value, then this pair of treatment is consider as significant.

Numerical :

$$LSD = t_{\frac{\alpha}{2}}(edf)\sqrt{\frac{2MSE}{r}}$$

$$LSD = t_{\frac{0.05}{2}}(9)\sqrt{\frac{2(\cancel{0.56}\ 1.006)}{4}}$$

$$\therefore t_{\frac{0.05}{2}} = t_{0.025}{}^{\times 9} = 2.26 \rightarrow \{\text{From t-distribution Table}$$

$$LSD = 2.26\left(\frac{0.709}{\cancel{4}}\right)$$

$$LSD = 1.602$$

(Average)*

Arranging treatments means in Ascending order:

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$\bar{X}_4$	$\bar{X}_1$	$\bar{X}_3$	$\bar{X}_2$
1.75	2.25	3.75	~~4.2~~ 4.5

$\bar{X}_1 - \bar{X}_4 = 2.25 - 1.75 = 0.5 \quad \therefore 0.5 < 1.602$ (insignific.

$\bar{X}_3 - \bar{X}_4 = 4.5 - 1.75 = 2 \quad \therefore 2 > 1.602$ (significant

$\bar{X}_3 - \bar{X}_1 = 3.75 - 2.25 = 1.5 \quad 1.5 < 1.602$ (insignific.

$\bar{X}_1 - \bar{X}_2 = \overset{4.5-}{2.25} \cancel{-4.2} =$ significant

$\bar{X}_2 - X_3 = 4.5 - 3.75 =$

$X_1 - X_4 < 1.60$

$X_3 - X_4 > 1.60$

$X_2 - X_4$

$(\bar{X}_4, \bar{X}_3)\ (\bar{X}_4, \bar{X}_2)\ (\bar{X}_1, \bar{X}_2)$

These are the significant pairs.

For Unequal Replications:

$$LSD = t_{\alpha/2}(v_2)\sqrt{2s_e^2\left(\frac{1}{n_1} + \frac{1}{n_2} + \dots + \frac{1}{n_{12}}\right.}$$

Block or Replication SS =

Treatment SS =

LATIN SQUARE DESIGN

In Latin Square Design, we control the two-sided variations by introducing Blocks. This Blocking is mutually perpendicular means from row-side & column-side. There is a balanced agreement b/w experimental material & exp. unit. Each Row & Coloumn have the homogeneous material within the groups.

Numerical :

5 fertilizers A, B, C, D, E were tested by arranging Plants in LS-Design in a field. The rows & coloumns in the table are rows & coloumns in the field. The yield in bushel is given below:

Day: M T W T F S   Date: __/__/20

Coloumns

Rows	1	2	3	4	5	Total	
R-1	B 4.9	D 6.4	E 3.3	A 9.5	C 11.8	35.9	
R-2	C 9.3	A 4.0	B 6.2	E 5.1	D 5.4	30	
R-3	D 7.6	C 15.4	A 6.5	B 6.0	E 4.6	40.1	
R-4	E 5.3	B 7.6	C 13.2	D 8.6	A 4.9	39.6	
R-5	A 9.3	E 6.3	D 11.8	C 15.9	B 7.6	50.9	
Total	C_1 36.4	C_2 39.7	C_3 41	C_4 45.1	C_5 34.3	$\boxed{196.5}$	Grand Total

Analysis the data for evidence at 5% level of significance, that the mean yields are not equal for the 5 fertilizers. Also pick up the best fertilizer.

Solution:

1- Hypothesis:

$H_0 = \mu_A = \mu_B = \mu_C = \mu_D = \mu_E$

H_1 atleast 1 is different

2- level of Significance:

$\alpha = 0.05$

or

5%

3- Test Statistics:

$F = \frac{S^2_t}{S^2_e}$

~~3~~ 4- Computation:

$$C.F = \frac{G^2}{k^2}$$

$$= \frac{(196)^2}{(5)^2}$$

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$$\cancel{3RE} = \frac{38612.25}{25}$$

$$= \boxed{1544.49}$$

TSS $= \sum\sum y_{ij}^2 - C.F$

$$= (4.9)^2 + (6.4)^2 + \ldots + (7.6)^2 - 1544.49$$

$$= 1829.83 - 1544.49$$

$$= \boxed{= 285.34}$$

Row SS $= \sum \frac{R_i^2}{k} - C.F$

$$= \frac{(35.9)^2 + (30)^2 + (40.1)^2 + (39.6)^2 + (50.9)^2}{5} - 1544.49$$

$$= \frac{(1288.8 + 900 + 1608.0 + 1568.1 + 2590.8)}{5} - 1544.4$$

$$= (7955.7/5)$$

$$= 1591.14 - 1544.4$$

$$= \boxed{= 46.74}$$

Coloumn RSS $= \sum \frac{C_j^2}{k} - C.F$

$$= \frac{(36.4)^2 + (39.7)^2 + (41)^2 + (45)^2 + (34)^2}{5} - 1544.49$$

$$= \frac{1324.9 + 1576.0 + 1681 + 2034.0 + 1176.4}{5} - 1544.4$$

$$= \frac{7791.4}{5} - 1544.49$$

$$= 1558.28 - 1544.4 = \boxed{= 13.79}$$

Treat SS $= \sum \frac{T_i^2}{k} - C.F$

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For Treat SS:-

A	B	C	D	E
9.5	4.9	11.8	6.4	3.3
4.0	6.2	9.3	5.4	5.1
6.5	6.0	15.4	7.6	4.6
4.9	7.6	13.2	8.6	5.3
9.3	7.6	15.9	11.8	6.3
T_1 34.2	T_2 32.3	T_3 65.6	T_4 39.8	T_5 24.6

$$\text{Treat SS} = \sum \frac{T_i^2}{k} - CF$$

$$= \frac{(34.2)^2+(32.3)^2+(65.6)^2+(39.8)^2+(24.6)^2}{5} - 1544.49$$

$$= \frac{8705.49}{5} - 1544.49$$

$$= 1741.098 - 1544.49 \quad \boxed{= 196.608}$$

Error SS = TSS - Treatment SS - Rows SS - Col. SS

$$= 285.34 - 196.608 - 46.67 - 14.02$$

$$\boxed{= 28.04}$$

Now ANOVA TABLE:-

Sov	d.f	SS	MSS	Formula
	$(k-1=?)$		$SS/df = ?$	$T.MSS / E\ MSS = ?$
Treatment	$5-1=4$	196.60	49.15	$F = 49.15/2.34$
Rows	4	46.67	11.66	
Columns	4	14.02	3.505	$F = 21.00$
Error	$(5-1)(5-2) = 12$	28.04	2.34	
Total	$k^2-1=5^2-1 = 24$	285.34		

Critical Region:

v_1 = column #.
v_2 = Row #.

$$F \geq F_\alpha (v_1, v_2)$$

$$F \geq F_{0.05}(4, 12)$$

$$21 \geq 3.26$$

Conclusion:

Reject H_0

After Mids

Multiple Comparison Test

1- Least Significant difference test
2. Duncon's Multiple range test
3. Factorial Test
4. Orthogonal Latin square test or Gratho Latin ~~~~ Square Design
5. Randomize ~~Block~~ Complete Block Design

Imp

Duncon's Multiple Range Test

→ Duncon's Multiple range test is used to compare the treatment means when Ho is rejected.

→ This test is based on different significant ranges which is obtained from studentized statistics $q(P,V)$.

→ where: "P" is the number of comparisons b/w the means

→ and "V" is the errors degrees of freedom from ANOVA table

→ then the value of $q(P,V)$ is obtained from Duncon's Table

→ The α percent least significant ranges are called R_p.

where $$\boxed{R_p = q_\alpha(P,V)\sqrt{\frac{S_e^2}{r}}}$$

with $P = 2, 3, 4, \dots k-1, k$

To perform this test,

1- arrange the treatment means in increasing order of magnitude &

2- Calculate the value of R_p by multiplying the Duncan's table value with mean square of error.

3- Compare the observed difference of largest (difference)' mean and smallest mean with Least significant range

4- (R_K) and compare the observed difference of largest mean and second smallest mean with Least significant Range (R_{K-1}) and so on

5- Continue this procedure until $K\left(\frac{k-1}{2}\right)$ comparisons are near.

⇒ A Treatment mean is significantly different of the observed differan is greater than the Least significant range.

Numerical:

$se^2 = 1.57$

$r = 4$

$RK = 4$

$\bar{X}_1 = 1.75$ $\bar{X}_2 = 3.50$

$\bar{X}_3 = 4.00$ $\bar{X}_4 = 4.75$

$\alpha = 0.05$

$edf = 15$

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Solution:

$$R_p = q_\alpha (P,V) \sqrt{\frac{Se^2}{r}}$$

$$\sqrt{\frac{Se^2}{r}} = \sqrt{\frac{1.57}{4}} = 0.6265$$

P	$q_\alpha (P,V)$ $q_{0.05} (P, 15)$	$R_P = q_\alpha (P,V) \sqrt{Se^2/r}$	
2	3.01	$(3.01)(0.6265) = 1.89$	R_2
3	3.16	$3.16 \times 0.6265 = 1.98$	R_3
4	3.25	$3.25 \times 0.6265 = 2.04$	R_4

⇒ Arrange in increasing order:-

$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$	$\bar{X}_4$
↓	↓	↓	↓
1.75	3.50	4.0	4.75

$$\therefore \frac{k(k-1)}{2} = \frac{4(4-1)}{2} = \frac{4(3)}{2} = 6$$

→ Comparison:-

$\bar{X}_4 - \bar{X}_1 = 4.75 - 1.75 = 3 > 2.04$ R_4

$\bar{X}_4 - \bar{X}_2 = 4.75 - 3.50 = 1.75 < \cancel{2.04}$ 1.98 R_3

$\bar{X}_4 - \bar{X}_3 = 4.75 - 4.00 = 0.75 < \cancel{2.04}$ 1.89 R_2

$\bar{X}_3 - \bar{X}_1 = 4.00 - 1.75 = 2.25 > \cancel{1.89}$ 1.98 R_3

$\bar{X}_3 - \bar{X}_2 = 4.00 - 3.75 = 0.5 < 1.89$ R_2

$\bar{X}_2 - \bar{X}_1 = 3.50 - 1.75 = 1.75 < 1.89$ R_2

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Numerical:

2^3 factorial experment with two varest measures (manures) fatks falls carried out in a randomized Complete Block Design with 3 replications. The Yield given in table:

	Treatment	Contributions				
Replications	V_1m_1	V_2m_2	V_2m_1	V_2m_2	Blocks	
R-1	5	7	8	10	30	B_1
R-2	4	4	7	5	20	B_2
R-3	6	2	9	12	31	B_3
Total:	$T_1 = 15$	$T_2 = 15$	$T_3 = 24$	$T_4 = 27$	81	$= G$

Perform analysis of variance & test the significance of varieties & manures

Solution:

1. Hypothesis:

H_0: there is no difference b/w treatment & combination

H_1: there is a difference

2. level of Significance:

$\alpha = 0.05$

3. Test Statistics:

$$F = \frac{S^2_t}{S^2_e}$$

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4. Computation:

$$C.F = \frac{(G)^2}{\cancel{k}n}.$$

$$= \frac{(81)^2}{12}$$

$=$

$= 546.75$

$$TSS = \sum\sum y_{ij}^2 - CF$$

$=$

$=$

$= 74.25$

$$ESS = \text{Treatment SS} = \sum \frac{Ti^2}{r} - C.F$$

$$= \frac{(\ )^2 + (\ )^2 + (\ )^2 + (\ )^2}{3} -$$

$=$

$= 38.25$

$$\text{Block SS} = \sum \frac{Bi^2}{k} - CF$$

$$= \frac{(\ )^2 + (\ )^2 + (\ )^2}{4} - 81$$

$= 18.50$

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Error SS = TSS - Trent. SS - Block SS

= 17.50

	m1	m2	Total
v1	15	15	30
v2	24	27	51
	39	42	81

Total SS = $\Sigma\Sigma y_{ij}^2$ - C.F = 38.25

Variety SS = $\frac{(30)^2 + (51)^2}{\text{average value} = 6}$ - CF 81 = 36.75

Manure MSS = $\frac{(39)^2 + (42)^2}{6}$ - CF 81

= 0.75

Interaction SS =

VMSS = Total SS - VSS - MSS

= 38.25 - 36.75 - 0.75

= 0.75

ANOVA TABLE

Error = total n - remaining values

ANOVA TABLE

Sor	df	SS	MS SS/df	F s^2t/s^2e
Treat	$t-1=$ 3			
Block	$b-1=$ 2			
Error	3		s^2e	
V	1			
M	1		s^2m	
VM	1			
Total	$n-1$ $12-1$ $=11$			

Critical Region:

$$F > F_\alpha (V_1, V_2)$$

Conclusion:

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Computation:

Radiation	a_0b_0	a_0b_1	a_1b_0	a_1b_1	Total
1	6	12	26	21	65
2	14	14	17	16	61
3	8	13	21	20	62
4	9	11	30	17	67
5	7	13	27	21	68
Total	44	63	121	95	323

$$CF = \frac{G^2}{r \times k}$$

$$\text{Treat SS} = \frac{\sum T_i^2}{r} - C.F$$

$$\text{Total SS} = \sum_i \sum y_{ij}^2 - CF$$

B \ A	a_0	a_1	total
b_0	44	121	165
b_1	63	95	158
Total	107	216	323

$$\text{Total SS} = \frac{(44)^2 + (121)^2 + (63)^2 + (95)^2}{5} - 323$$

=

$$ASS = \frac{(107)^2 + (216)^2}{10} - 323$$

=

$$BSS = \frac{(165)^2 + (158)^2}{10} - 323$$

$ABSS = \text{Total SS} - ASS - BSS$

"ORTHOGONAL LATIN SQUARE DESIGN"

(or)

Also known as "Gratho Linkin Square design"

- It control 3 way variation.
- By superimposing two latin designs.
- But one restriction / condition:

"Each Latin letter must appear single time with each greek letter."

A	B	C
B	C	A
C	A	B

+

α	β	γ
γ	β	α
γ	α	β

$A\alpha$		

wrong

- It control 3 sided variations.

Two latin Square

I

A	B	C	D
B	A	D	C
C	D	A	B
D	C	B	A

II

α	β	γ	δ
δ	γ	α	β
γ	δ	β	α
β	α	δ	γ

Superimpose Square III

A α	B β	C γ	D δ	$R_1=$
B δ	A γ	D α	C β	$R_2=$
C γ	D δ	A β	B α	$R_3=$
D β	C α	B δ	A γ	$R_4=$
$C_1=$	$C_2=$	$C_3=$	$C_4=$	→ Grand Total

3 way variation:

- Row side
- Coloumn side
- Greek letter

Computation:

$$C.F = \frac{G^2}{k^2}$$

$$TSS = \sum\sum\sum Y_{ijk}^2 - C.F$$

$$Row\ SS = \sum \frac{R^2}{k} - CF$$

TSS =

$$= \frac{R_1^2 + R_2^2 + R_3^2 + R_4^2}{4} - CF$$

$$Col.\ SS = \sum \frac{C^2}{k} - CF$$

$$= \frac{C_1^2 + C^2 + C^3 + C_4^2}{4} - CF$$

For Treatment SS :

Arrange the table according to alphabets.

Randomization

then:

Treat SS = $\frac{\Sigma T^2}{k}$ - CF

$= \frac{T_1^2 + T^2 + T^3 + T^4}{k}$ - CF

Now arrange table according to greek letters:

Greek SS = $\frac{\Sigma G.^2}{k}$ - C.F

$= \frac{\alpha_i^2 + \beta^2 + \gamma_i^2 + \delta^2}{4}$ - CF

Error SS = Total SS - Row SS - Col. SS - Treat SS - Greek SS

ANOVA TABL

Sov	df	SS	MS	F
Treat	k-1=3			st^2/se^2
Raw	k-1=3			
Coloumn	k-1=3			
Greek	k-1=3			
Error	n-1=? ✗ k-1=15			
Total	k^2-1=? 4^2-1=15			

Error = Total mn sy baqi sb k total minus krny hein.

15 - 12 = 3