Simple Experiments and The Types of Design:

1. Complete Randomized Design (CRD):

The CRD idea:

- No. of treatments (t)=4
- No. of replicates for each treatment (r)= 3 times
- No. of experimental units = t*r=4*3=12
- Prepare (12) Slips of paper and mixed them then distribute them randomly on homogenous units.

t1	t1	t1	t2	t2	t2	t3	t3	t3	t4	t4	t4

Draw out the first slip and allotted on exp. Unit no.1 then draw the next slip and allotted on exp. Unit no.2 … etc

t2	t4	t3	t2
t1	t2	t3	t4
t3	t1	t4	t1

Example (1): The study was conducted to test the effect of [4] different media on growth radius of fungi at the same enviromental condition using [5] replicates ,and you are given these results:

Treatments	r1	r2	r3	r4	r5	sum of treat.
t1	3	4	5	6	6	24
t2	6	5	6	7	10	34
t3	5	6	7	6	8	32
t4	10	9	9	12	13	53
						$G=\sum x_{ij}=143$

Construct the ANOVA Table under (α=0.01), calculate the treatment, experimental error and general mean effects of experiment.

Total SS= $\sum x^2_{ij}$ – C.F.

$$\sum x^2_{ij} = 3^2 + 4^2 + 5^2 + \ldots + 12^2 + 13^2 = 1153$$

$$C.F. = \frac{(143)^2}{5*4} = 1022.45$$

$$SS_{Total} = 1153 - 1022.45 = 130.55$$

$$SS_{treat.} = \frac{24^2 + \ldots + 53^2}{5} - 1022.45 = \frac{5565}{5} - 1022.45 = 90.55$$

SS_{Error}=130.55-90.55=40
MS_t=90.55/3=30.183
MS_E=40/16=2.5
Cal.F=30.183/2.5=12.07
From special statistical tables we obtain:
$Tab.F_{(0.01,3,16)}$=5.29

ANOVA Table

S.O.V.	df	SS	MS	Cal.F	$Tab.F_{0.01}$
Treatment	3	90.55	30.183	12.07**	5.29
Error	16	40	2.5		
Total	19	130.55			

Since Cal.F more than Tab.F it means that there are significance differences between treatments, or the treatments have significant. effect on growth radius of fungi in the experiment.

Exp.(2): From the following data complete ANOVA table then the significancy of treatments at L.S.=0.05 and 0.01.

Treatments	*rep.1*	*rep.2*	*rep.3*	*rep.4*	*Σ of treatment*
t_1	2.3	3.1	2.9	3.2	11.5
t_2	4.6	5.5	3.5	4.2	17.8
t_3	3.5	4.6	3.8		11.9
t_4	2.9	3.0	4.0	4.0	13.9
t_5	3.9	2.8	3.7		10.4

$\Sigma x_{IJ} = G = 65.5$

No. of exp. Units= Σri =4+4+3+4+3=18

df_t= t-1=4 and df_T = Σri -1 =18-1 =17

C.F. = $(G)^2/\Sigma ri = (65.5)^2/18 = 238.35$

SS total= Σx^2_{IJ} – C.F

SST=$(2.3)^2+(3.1)^2+$-----------$+(4.0)^2$-238.35=10.5

=248.85-238.35=10.5

$$SS_t = \frac{(11.5)^2}{4} + \frac{(17.8)^2}{4} + \frac{(11.9)^2}{3} + \frac{(13.9)^2}{4} + \frac{(10.4)^2}{3} - 238.35$$

$$= 243.82 - 238.35 = 5.47$$

$$SS_E = 10.5 - 5.47 = 5.03$$

ANOVA Table

S.O.V.	df	SS	MS	Cal.F	Tab.F
Treatment	4	5.47	1.37	3.425* 3.425$^{n.s}$	$3.179_{(0.05)}$ $5.205_{(0.01)}$
Error	13	5.03	0.38		
Total	17	10. 5			

From the above ANOVA table appears that there are significant different between the treatments at L.S. (0.05) only.

Q1/ From the following information complete ANOVA table:

No. of exp. units=25 , SS_E=0.9 , C.F.=13.25

No. of treatment=5 , cal-F=2

- *Multiple comparison test:*

Q1/ From example (1) compare between theg treatments:

Treatments	sum	means
t1	24	24/5=4.8
t2	34	34/5=6.8
t3	32	32/5=6.4
t4	53	53/5=10.6

Means	$\bar{t}_1 = 4.8$	$\bar{t}_3 = 6.4$	$\bar{t}_2 = 6.8$	$\bar{t}_4 = 10.6$
$\bar{t}_4 = 10.6$	$\bar{t}_4 - \bar{t}_1 = 10.6 - 4.8 = 5.8^{**}$	$10.6 - 6.4 = 4.2^{**}$	$10.6 - 6.8 = 3.8^{**}$	0
$\bar{t}_2 = 6.8$	$6.8 - 4.8 = 2.0^{\mathbf{n.s.}}$	$6.8 - 6.4 = 0.4^{\mathbf{n.s.}}$	0	
$\bar{t}_3 = 6.4$	$6.4 - 4.8 = 1.6^{\mathbf{n.s.}}$	0		
$\bar{t}_1 = 4.8$	0			

$$1 - LSD_\alpha = tab.t_{\alpha, df_{error}} \sqrt{\frac{2MSE}{r}} \quad or \quad = tab.t_{\alpha, df_{error}} \sqrt{2}\, S_{\bar{x}}$$

$$LSD_{0.01} = tab.t_{(0.01,16)} \sqrt{\frac{2(2.5)}{5}} = 2.921\sqrt{1} = \mathbf{2.921}$$

There are significant. differences between (t_1 and t_4), (t_3 and t_4) and (t_2 and t_4)

but no significant differences between (t_1 and t_2), (t_3 and t_2) and (t_1 and t_3).

$$2-RLSD_{\alpha} = tab.t' \sqrt{\frac{2MSE}{r}}$$

$$RLSD_{0.01} = tab.t' \sqrt{\frac{2(2.5)}{5}} = (2.66)\sqrt{1} = 2.66$$

There are sig. differences between (t_1 and t_4), (t_3 and t_4), (t_2 and t_4) but no sig. differences between (t_1 and t_2), (t_3 and t_2) & (t_1 and t_3).

Also we can use DMRT and Dunnett's test.

Exp.(2): A study was conducted to compare between the effect of (3) types of meat on blood cholesterol, if the number of donors are (12) homogenous donors if you are given the following data complete ANOVA table, then select the best type of meat at level of significance 0.01 .

Type of meat	1	2	3	4	5	sum	mean
Sheep	145	147	151	149	152	744	148.8
Turkey	130	129	133			392	130.67
Fish	132	131	126	130		519	129.75
						1655	

$\sum ri=5+3+4=12$

C.F.$=(1655)^2/12=228252.08$

SST$=(145)^2+\ldots+(130)^2-228252.1=229331-228252.1=1078.9$

$$SS_t = \frac{(744)^2}{5} + \frac{(392)^2}{3} + \frac{(519)^2}{4} - 228252.1 = 229268.8 - 228252.1 = 1016.7$$

$$SS_E = 1078.9 - 1016.7 = 62.2$$

ANOVA table

S.O.V.	df	SS	MS	Tab.$F_{0.01}$	Cal.F
Treatment	2	1016.7	508.35	8.02	73.56*
Error	9	62.2	6.91		
Total	11	1078.9			

$$K_o = \frac{1}{t-1}\left(\sum r_i - \frac{\sum r_i^2}{\sum r_i}\right) = \frac{1}{2}\left(12 - \frac{25+9+16}{12}\right) = 3.92$$

$$LSD_\alpha = tab.t_{\alpha, df_{error}} \sqrt{\frac{2MSE}{K_o}}$$

$$LSD_{0.01} = tab.t_{(0.01,9)} \sqrt{\frac{2(6.91)}{3.92}} = 3.25\sqrt{3.52} = \mathbf{6.1}$$

$$\bar{t}_1 = 148.8 \qquad t_2 = 130.67 \qquad \bar{t}_3 = 129.75$$

$$\bar{t}_1 - \bar{t}_2 = 148.8 - 130.67 = 18.13^{**}$$

$$\bar{t}_1 - \bar{t}_3 = 148.8 - 129.75 = 19.05^{**}$$

$$\bar{t}_2 - \bar{t}_3 = 130.67 - 129.75 = 0.92^{n.s.}$$

, t_1 is the best type of meat.

Exp.1/ The pot experiment was conducted in glass house for testing the infection of 4 varieties of wheat with black stem rust disease, test the effect of varieties on wheat infection with rust disease. Complete ANOVA table then compare between them using $LSD_{0.05}$, $RLSD_{0.05}$ and Duncan test.

Treat.	r1	r2	r3	r4	∑ti	means
A	9	8	9	10	36	9
B	8	7	7	9	31	7.75
C	7	5	6	6	24	6
D	9	12	8	13	42	10.5
					G=133	

C.F. $=(133)^2/4*4=1105.56$

$\Sigma x^2_{ij}=(9)^2+(8)^2+...+(13)^2=1173$

SST=1173-1105.56=67.44

$$SS_t=\frac{(36)^2+(31)^2+(24)^2+(42)^2}{4}-1105.56=1149.25-1105.56=43.7$$

$$SS_E=67.44-43.7=23.74$$

$$MS_t=43.7/3=14.57$$

$$MS_E=23.74/12=1.98$$

$$Cal.F=14.57/1.98=7.36$$

ANOVA Table

S.O.V.	df	SS	MS	Tab.$F_{0.05}$	Cal.F
Treatment	3	43.7	14.58	3.49	7.36*
Error	12	23.74	1.98		
Total	15	67.44			

$\bar{t}_4$	$\bar{t}_1$	$\bar{t}_2$	$\bar{t}_3$
10.5	9.0	7.75	6.0
a	ab	bc	c

$$\bar{t}_4 - \bar{t}_1 = 10.5 - 9.0 = 1.5^{n.s.}$$

$$\bar{t}_4 - \bar{t}_2 = 10.5 - 7.75 = 2.75^{*}$$

$$\bar{t}_4 - \bar{t}_3 = 10.5 - 6.0 = 4.5^{*}$$

$$\bar{t}_1 - \bar{t}_2 = 9.0 - 7.75 = 1.25^{n.s.}$$

$$\bar{t}_1 - \bar{t}_3 = 9.0 - 6.0 = 3.0^{*}$$

$$\bar{t}_2 - \bar{t}_3 = 7.75 - 6.0 = 1.75^{n.s.}$$

$$LSD_{\alpha} = tab.t_{\alpha, df_{error}} \sqrt{\frac{2MSE}{r}}$$

$$LSD_{0.05} = tab.t_{(0.05,12)} \sqrt{\frac{2(1.98)}{4}}$$

$$= 2.179(0.99) = \mathbf{2.16}$$

$$LSD'_{0.05} = tab.t'_{(0.05,3,12,7.36)} \sqrt{\frac{2(1.98)}{4}}$$

$$= 2.1(0.99) = \mathbf{2.079}$$

$$LSR = SSR\sqrt{MS_E / r}$$

$$S_{\bar{x}} = \sqrt{1.98/4} = 0.7$$

	2	3	4
SSR	3.08	3.23	3.33
SE=0.7			
LSR	2.156	2.261	2.331

Means	LSR	$\bar{t}_3$	$\bar{t}_2$	$\bar{t}_1$	$\bar{t}_4$
$\bar{t}_4 = 10.5$	2.331	4.5*	2.75*	1.5 n.s.	0
$\bar{t}_1 = 9.0$	2.261	3.0*	1.25 n.s.	0	
$\bar{t}_2 = 7.75$	2.156	1.75 n.s.	0		
$\bar{t}_3 = 6.0$	---	0			

There are significance differences between (t_4 and t_3),(t_4 and t_2) & (t_1 and t_3)

Exp.5/ A study was conducted to compare between the effect of (5) types of cool drinks (no color, red, yellow, orange and green) on increase of human weight [gm/day] and you are given the following information, construct ANOVA table at 0.05 if (t1 is control treatment and experimental units are uniform).

Treat.	r1	r2	r3	r4	r5	sum	means
No color	25.1	29.0	27.3	26.5	28.4	136.3	27.3
Red	28.3	27.9	30.6	31.3	29.8	147.9	29.6
Yellow	28.9	25.6	23.7	25.1	25.0	128.3	25.7
Orange	25.4	28.5	26.9	24.6	27.1	132.5	26.5
Green	31.8	29.6	29.5	32.0	31.7	154.6	30.9
						G=699.6	

C.F.$=(699.6)^2/25=19577.6$

$\Sigma x^2_{ij}=(25.1)^2+(29)^2+\ldots+(31.7)^2=19722.9$

SST$=19722.9-19577.6=145.3$

$$SS_{treat.}=\frac{(136.3)^2+\ldots+(154.6)^2}{5}-19577.6$$

$$=19674.1-19577.6=96.5$$

$$SS_{Error}=145.3-96.5=48.8$$

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.05}$
Treatment	4	96.5	24.125	9.88*	2.87
Error	20	48.8	2.44		
Total	24	145.3			

Since the cal-F is more than tab-F we reject H_o that's mean the treatments having sig. effect.

•*Dunnett's test:*

$$\bar{t}_2 - \bar{t}_1 = 29.6 - 27.3 = 2.3^{n.s.} \qquad \bar{t}_3 - \bar{t}_1 = 25.7 - 27.3 = -1.6^{n.s.}$$

$$\bar{t}_5 - \bar{t}_1 = 30.9 - 27.3 = 3.6^{*} \qquad \bar{t}_4 - \bar{t}_1 = 26.5 - 27.3 = -0.8^{n.s.}$$

$$D_t = tab.t_{D(\alpha, df_t, df_E)} \sqrt{2MS_E / r} = tab.t_{D(0.05,4,20)} \sqrt{2(2.44)/5}$$

$$D_t = 2.7(0.98) = \mathbf{2.66}$$

There are differences between (t1) and (t5), (t5) is the best.

Q/ From the following data compare between treatments if the (t4) is control.

N-fertilizer.	r_1	r_2	r_3	r_4
N_{30}	55	70	64	63
N_{20}	58	59	67	63
N_{10}	52	56	51	56
N_0	49	50	46	52

2. *Randomized Complete Block Design (RCBD):*

Exp./ the following data obtained from a field experiment to test the effect of (5) cultivars of broad bean on the weight of nodules gm/plant using (6) blocks (replicates), compare between the cultivars (use $RLSD_{0.05}$ and Duncan's test).

Cult.	B1	B2	B3	B4	B5	B6	∑	mean
t1	4	4	5	3	4	2	22	3.67
t2	4	3	4	5	5	4	25	4.16
t3	2	3	5	3	6	7	26	4.33
t4	5	5	5	8	9	11	43	7.16
t5	4	5	3	7	7	10	36	6.00
∑	19	20	22	26	31	34	G=152	

C.F.=$(152)^2/5*6=770.13$ Total SS=$(4^2+4^2+...+10)$ - CF =143.87

Tota lSS=914-770.13=143.87

$$SS_{treat}=\frac{(22)^2+...+(36)^2}{6}-770.13=821.67-770.13=51.54$$

$$SS_{Block}=\frac{(19)^2+...+(34)^2}{5}-770.13=807.6-770.13=37.47$$

$$SS_{Error} = 143.87 - 51.54 - 37.47 = 54.86$$

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.05}$
Treatment	4	51.54	12.88	4.7*	2.87
Block	5	37.47	7.49	2.7	
Error=(t-1)(r-1)	20	54.86	2.74		
Total	29	143.87			

While cal-F more than tab-F reject H_o that's mean the treatments have sig. effect on the weight.

Means	$\bar{t}_1 = 3.67$	$\bar{t}_2 = 4.16$	$\bar{t}_3 = 4.33$	$\bar{t}_5 = 6.0$	$\bar{t}_4 = 7.16$
$\bar{t}_4 = 7.16$	3.49^{*}	3.0^{*}	2.83^{*}	$1.16^{n.s.}$	0
$\bar{t}_5 = 6.0$	2.33^{*}	$1.84^{n.s.}$	$1.67^{n.s.}$	0	
$\bar{t}_3 = 4.33$	$0.66^{n.s.}$	$0.17^{n.s.}$	0		
$\bar{t}_2 = 4.16$	$0.49^{n.s.}$	0			
$\bar{t}_1 = 3.67$	0				

$$RLSD_{0.05} = tab.t'_{(0.05,4,20,4.7)}\sqrt{\frac{2(2.74)}{6}} = (2.14)(0.95) = \mathbf{2.033}$$

Complete the test by finding SSR and LSR values then specify letters for significance of the treatments.

Q/ from the following information compare between the (4) types of insecticides. Test the study using LSD

Sum of blocks are (220, 228, 242 and 238) respectively,

Sum of treatments are (160, 285, ------- and 235) respectively, Tab.$F_{0.05}$=3.86 , tab.$t_{0.05}$=2.262 and SS_{Total}=2286

- *Missing value in RCBD:*

Exp.1/ A study conducted for testing the effect of (5) types of forages on increasing of milk products in cows with (4) blocks, from the following data an observation missed in any way. Estimate the missing value then complete adjusted ANOVA.

Forages	1	2	3	4	∑ of treatments	
Type1	1.6	1.7	1.9	1.6	6.8	
Type2	1.9	2.0	1.9	1.8	7.6	
Type3	1.7	1.8	2.1	1.9	7.5	
Type4	1.3	1.4	1.625	1.5	4.2	5.83
Type5	1.6	1.3	1.8	1.5	6.2	
∑ of blocks	8.1	8.2	7.7	8.3	G=32.3	
			9.33		G=33.93	

1/ Approximated method:

Mean of t4=(4.2)/3=1.4

Mean of b3=(7.7)/4=1.925

m.v. = (x_{43})=(1.4+1.925)/2=1.6625≈1.7

2/ Yate's method:

$$x_{ij} = x_{43} = \frac{tT + rR - G}{(t-1)(r-1)} = \frac{5(4.2) + 4(7.7) - 32.3}{4*3} = 1.625$$

C.F.=$(33.93)^2/5*4=57.56$

SST=58.51-57.56=0.95

$$SS_t = \frac{(6.8)^2 + \ldots(5.83)^2 + (6.2)^2}{4} - 57.56 = 58.17 - 57.56 = 0.61$$

$$SS_{Block} = \frac{(8.1)^2 + \ldots(9.33)^2 + (8.3)^2}{5} - 57.56 = 57.76 - 57.56 = 0.2$$

$$SS_E = 0.95 - 0.61 - 0.2 = 0.14$$

ANOVA Table

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.05}$
Treatment	4	0.61	0.15	13.63*	3.26
Block	3	0.2	0.06	5.45	
Error	12-1	0.14	0.013		
Total	19-1	0.95			

$$SS_t' = 0.61 - \frac{[(7.7)-(5-1)(1.625)]^2}{5(5-1)} = 0.54$$

Adjusted ANOVA table

S.O.V.	df	SS	MS	Cal.F	$Tab.F_{0.05}$
Treatment	4	0.54	0.135	6.75*	3.36
Block	3	0.2	0.06	3.0	
Error	12-1=11	0.21	0.02		
Total	19-1=18	0.95			

Q/ The following data represent a data obtained from a field experiment. Estimate the missing value then complete Adjusted Table.

	t1	t2	t3	t4
B1	23	---	25	27
B2	24	25	24	26
B3	23	25	25	24
B4	22	26	22	23

Latin square design (LSD): •

The most important points or properties of latin square design are: •

1-The number of treatments = The number of replications =Number of rows =number of columns. •

2-The df error(dfe)) must be = 6 or more. •

3-The experimental units are differing in two directions or properties. •

4-This design is not allowed in case of {3x3) because in this case the dfe =2. •

s.o.v	df	ss	MS	Calc.F
Treats	t-1			
Rows	t-1			
Columns	t-1			
Error	$(t-_1)(t-_2)$			
Total	t^2-1			

5-Sum of rows =sum of columns =sum of treatments=G =sum of data.
6-In this design the treatments must repeats once in row and column.
7-this design uses rarely in field experiments or it is not uses widely in agricultural experiments because its construction needs more time ,money and work, because needs large number of experimental units in comparing with RCBD ,because number of treatments = number of replicates while in RCBD the number of replicates = 3 or more, for example if the the number of treatments =10
a-In case of Latin square design the researcher needs 100 experimental units because t=r=10 then 10x10=100.
b-In case of RCBD if the number of replicates =3 the researcher will needs 10x3 =30 experimental units.
8- The mathematical model is differing from mathematical model of CRD and RCBD.
9- Missing value causes the difficulties in statistical analysis.

3. *Latin Square Design (LSD):*

Exp.1/ From the following data complete ANOVA table then compare between the insecticides at level of significance = 0.05, if the Statistical Model is:

$$x_{ijk} = \mu + \tau_i + R_j + C_k + \varepsilon_{ijk}$$

$$i = 1,2,3,4$$

$$i = j = k$$

$t^2=4*4=16$	Col.1	Col.2	Col.3	Col.4	∑rows	∑treatment
Row1	A_1 *14*	B_1 11	C_1 **12**	D_1 11	48	∑A=60
Row2	B_2 12	C_2 **13**	D_2 18	A_2 *15*	58	∑B=46
Row3	C_3 **15**	D_3 15	A_3 *14*	B_3 11	55	∑C=57
row4	D_4 10	A_4 *17*	B_4 12	C_4 **17**	56	∑D=54
∑columns	51	56	56	54	G=217	

C.F.= $(217)^2/16=2943.0625$ $\sum x^2_{ijk}=(14)^2+\ldots+(17)^2=3033$

SST=3033-2943.0625=89.94

$$SS_{treat.}=\frac{(60)^2+\ldots+(54)^2}{4}-2943.0625=2970.25-2943.0625=27.2$$

$$SS_{Block}=\frac{(48)^2+\ldots+(56)^2}{4}-2943.0625=2957.25-2943.0625=14.2$$

$$SS_{Column}=\frac{(51)^2+\ldots+(54)^2}{4}-2943.0625=2947.25-2943.0625=4.2$$

$$SS_{Error}=89.94-27.2-14.2-4.2=44.34$$

$MS_t=27.2/3=9.07$ $\quad$ $MS_{Row}=14.2/3=4.7$

$MS_{Col.}=4.2/3=1.4$ $\quad$ $MS_E=44.34/6=7.4$

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.05}$
Treatment	3	27.2	9.07	1.22 n.s.	4.76
Block	3	14.2	4.7		
Column	3	4.2	1.4		
Error	6	44.34	7.4		
Total	15	89.94			

While cal.F less than Tab.F , it means that there are no sig. differences between the insecticides.

Exp.2/ An experiment was conducted to study the effect of (6) types of chemical fertilizers on yield of sugar cane (ton/Acer), compare treatments at level of significance 0.05, if A= control treatment.

Columns

	1	2	3	4	5	6	∑rows	∑treat
R1	C 29.6	D 26.4	E 33.2	F 30.5	A 31.8	B 33.0	184.5	176.8
2	D 28.8	E 29.4	F 29.9	A 25.9	B 27.4	C 30.1	171.5	176.9
3	E 30.6	F 30.8	A 28.3	B 30.4	C 32.0	D 21.7	173.8	184.0
4	F 26.7	A 29.0	B 29.2	C 32.0	D 26.6	E 28.9	172.4	155.1
5	A 31.4	B 28.5	C 30.8	D 23.9	E 31.3	F 33.2	179.1	183.0
6	B 28.4	C 29.5	D 27.7	E 29.6	F 32.1	A 30.4	177.7	183.2
∑col.	175.5	173.6	179.1	172.3	181.2	177.3		G=1059

$C.F. = 31152.25$ $SS_{Total} = 31374.3 - 31152.25 = 222.05$

$SS_{treat.} = 31252.52 - 31152.25 = 100.27$

$SS_{Row} = 31172.5 - 31152.25 = 20.25$

$SS_{Column} = 31161.67 - 31152.25 = 9.42$

$SS_{Error} = 92.11$

ANOVA Table

s.o.v.	df	SS	MS	Cal.F	Tab-F
Treat.	5	100.27	20.054	4.35*	2.71
Row	5	20.25	4.05		
Column	5	9.42	1.884		
Error	20	92.11	4.605		
Total	35	222.05			

$$\bar{t}_2 - \bar{t}_1 = 29.5 - 29.5 = 0.0$$

$$\bar{t}_3 - \bar{t}_1 = 30.7 - 29.5 = 1.2$$

$$\bar{t}_4 - \bar{t}_1 = 25.85 - 29.5 = -3.65^{*}$$

$$\bar{t}_5 - \bar{t}_1 = 30.5 - 29.5 = 1.0$$

$$\bar{t}_6 - \bar{t}_1 = 30.53 - 29.5 = 1.03$$

$$D_t = tab.t_{D(\alpha, df_t, df_E)} \sqrt{2MS_E / r} = tab.t_{D(0.05,5,20)} \sqrt{2(4.605)/6}$$

$$D_t = 2.81(1.24) = \mathbf{3.5}$$

- *Missing value in Latin Square Design:*

Exp./from the following data calculate missing value:

25	c1	c2	c3	c4	∑rows	∑treat
R1	C19	A17	B16	D18	70	∑A=66
R2	D16	B15	C15	A16	62	∑C=67
R3	A18	C17.3	D14	B19	51→68.3	∑C=48→ 65.3
R4	B17	D19	A15	C14	65	∑D=67
∑col.	70	51 68.3	60	67	G=248 → 265.3	

$$x_{ijk} = x_{323} = \frac{r(R+C+T)-2G}{(r-1)(r-2)} = \frac{4(51+51+48)-2(248)}{3*2} = 17.3$$

$$C.F. = \frac{(265.3)^2}{16} = 4399$$

$$SST = 4443.3 - 4399 = 44.3$$

$$SS_t = 4399.5 - 4399 = 0.5 \qquad SS_R = 4408.5 - 4399 = 9.5$$

$$SS_C = 4413.5 - 4399 = 14.5 \qquad SS_E = 19.8$$

$$AdjSS_t = SS_t - \frac{[G-R-C-(t-1)T]^2}{[(t-1)(t-2)]^2} = 0.5 - \frac{[248-51-51-(4-1)(48)]^2}{[3*2]^2} = 0.4$$

ANOVA Table

s.o.v.	df	SS	MS	Cal.F	Tab-F
Treat.	3	0.4	0.13	0.03 n.s.	
Row	3	9.5	3.16		
Column	3	14.5	4.83		
Error	6-1=5	19.8	3.96		
Total	15-1=14	44.2			

- *Relative Efficiency (RE):*

Q/ from the following ANOVA calculate the RE:

1) Approximately

RCBD ANOVA Table

s.o.v.	df	SS	MS
Treat.	3	135.2	45.1
Block	4	21.5	5.4
Error	12	26.3	2.2
Total	19	183	

→

CRD ANOVA Table

s.o.v.	df	SS	MS
Treat.	3	135.2	45.1
Error	16	47.8	2.98
Total	19	183	

$$RE(RCBD:CRD) = \frac{MSE_{CRD}}{MSER_{CBD}} * 100 = (2.98/2.2)*100 = 135.4\%$$

RCBD more efficiency than CRD about 35.4%, using RCBD increase the efficiency of experiment about 35.4%

- Rep. =5 in RCBD
- 5*1.354 =6.77 in CRD

2) $MSE_{CRD} = \frac{SSB + (df_t + df_E)\, MSE}{df_T} = \frac{21.5+(3+12)*2.2}{19} = 2.87$

RE(RCBD:CRD)=(2.87/2.2)*100=130.4%

It means RCBD more efficient than CRD about 30.4%

Q/From the following ANOVA table calculate the RE(RCBD:CRD):

s.o.v.	rdf	SS	MS		s.o.v.	df	SS	MS
Block	4	2.04	0.51	→	Treat	4	1.32	0.33
Treat	4	1.32	0.33	→				
Error	16	1.005	0.063	→	Error	20	3.045	0.152
Total	24	4.365			Total	24	4.365	

$$RE(RCBD:CRD) = \frac{MSE_{CRD}}{MSE_{RCBD}} * \frac{(n_1+1)(n_2+3)}{(n_1+3)(n_2+1)} * 100$$

$$= \frac{0.152}{0.063} * \frac{(16+1)(20+3)}{(16+3)(20+1)} * 100 = 236.5\% \quad RCBD \text{ more efficient than CRD}$$

$$236.5/100 = 2.365 \Rightarrow 5*2.365 = 11.83 \text{ rep. in CRD}$$

Q/ From the following LSD ANOVA, calculate the RE(LSD:CRD) ,and RE(LSD:RCBD).

s.o.v.	df	SS	MS
Column	4	2.18	0.54
Block (Row)	4	2.4	0.6
Treat	4	1.92	0.48
Error	12	1.07	0.1
Total	24	7.57	

$$RE(LSD:CRD) = \frac{MS_r + MS_c + (r-1)MS_E}{(r+1)MS_E} = \frac{0.6 + 0.54 + (4)(0.1)}{(6)(0.1)} * 100$$

$$= \frac{1.54}{0.6} * 100 = 256.6\% \quad \text{LSD more efficient than CRD about } 156.6\%$$

$$RE(LSD:RCBD) = \frac{MS_c + (r-1)MS_E}{rMS_E} = \frac{0.54 + (4)(0.1)}{(5)(0.1)} * 100$$

$$= 188\% \quad \text{LSD more efficient than RCBD when rows becomes Blocks.}$$

$$RE(LSD:RCBD) = \frac{MS_r + (r-1)MS_E}{rMS_E} = \frac{0.6 + (4)(0.1)}{(5)(0.1)} * 100$$

$$= 48\% \quad \text{LSD less efficient than RCBD when columns becoms blocks.}$$

- **Factorial experiments:** It is an experiment which includes two factors or more
- The basic symbols in factorial experiments:
- 1- Symbol of factor is capital letter like ,A ,B ,C,W,N ,M……..
.2-Symbol of levels of factor is small letter like a1, a2, a3. a4 or a0 ,a1 ,a2…….or b1 ,b2…….
- 3-Treatment combinations (T.C.) =Levels of factor A x levels of B factor
- Like a1b1 a1b2 a2b2 ,……………………
- Basic terms in factorial experiments:
- 1- Simple effects :It is the difference between two levels of a certain Factor
- at the same levels of the other factor.
- 2-Main effect: It is the mean for the sum of two simple effects.
- 3-Interaction effect: It is the mean for the difference between two simple

	b1	b2	simple effects
a1	a1b1	a1b2	a1b1 – a1b2
a2	a2b1	a2b2	a2b1 – a2b2
Simple effects.	a1b1-a2b1	a1b2-a2b2	

❖ *Factorial Experiments (Multifactor):*

Exp./ A factorial experiment was conducted for controlling fusarium wilt disease of cotton seedling using (2) fungicides each of them with (3) concentrations, the number of replicates = (3)and the following data represent the no. of infected seeds. Complete the ANOVA under (LSD0.05).

Fung.	Concen.	Rep.1	Rep.2	Rep.3	Sum of treat. Com.
a_0	b_0	16	13	17	$46 = \sum a_0b_0$
	b_1	10	10	13	$33 = \sum a_0b_1$
	b_2	8	10	9	$27 = \sum a_0b_2$
a_1	b_0	14	13	11	$38 = \sum a_1b_0$
	b_1	12	13	9	$34 = \sum a_1b_1$
	b_2	3	3	4	$10 = \sum a_1b_2$
Total					G=188

AB table

	b_0	b_1	b_2	$\sum a$
a_0	46	33	27	106
a_1	38	34	10	82
$\sum b$	84	67	37	G=188

$$C.F. = \frac{(188)^2}{2*3*3} = 1963.5$$

$$SS_{T.C.} = \frac{(46)^2 + ...(10)^2}{3} - 1963.5 = 2211.3 - 1963.5 = 247.8$$

$$SSA = \frac{(106)^2 + (82)^2}{3*3} - 1963.5 = 32.05$$

$$SSB = \frac{(84)^2 + (67)^2 + (37)^2}{2*3} - 1963.5 = 188.83$$

$$SSAB = SS_{T.C.} - (SSA + SSB) = 247.8 - 32.05 - 188.83 = 26.92$$

$$SST = (16)^2 + (13)^2 + ... + (4)^2 - 1963.5 = 278.5$$

$$SSE = SST - SS_{T.C.} = 278.5 - 247.8 = 30.7$$

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.05}$
T.C.	6-1=5	247.8	49.56	19.4 *	3.11
A	2-1=1	32.05	32.05	12.52 *	4.75
B	3-1=2	188.83	94.42	36.9 *	3.89
AB	2	26.92	13.5	5.3 *	3.89
Error	6*2=12	30.7	2.56		
Total	2*3*3-1=17	278.5			

$$LSD_{\alpha=0.05}A = tab.t_{df_e=(12)}\sqrt{\frac{2MSE}{3*3}} = 2.179*\sqrt{\frac{2(2.56)}{9}} = 1.64$$

$$LSD_{\alpha=0.05}B = tab.t_{df_e=(12)}\sqrt{\frac{2MSE}{2*3}} = 2.179*\sqrt{\frac{2(2.56)}{6}} = 2.01$$

$$LSD_{\alpha=0.05}AB = tab.t_{df_e=(12)}\sqrt{\frac{2MSE}{3}} = 2.179*\sqrt{\frac{2(2.56)}{3}} = 2.8$$

$$\bar{a}_0 = \frac{\sum a_0}{br} = \frac{106}{3*3} = 11.8 \qquad \bar{a}_1 = \frac{82}{9} = 9.1 \qquad \bar{a}_0 - \bar{a}_1 = 11.8 - 9.1 = 2.7*$$

$$\bar{b}_0 = \frac{\sum b_0}{ar} = \frac{84}{2*3} = 14 \qquad \bar{b}_1 = \frac{67}{6} = 11.2 \qquad \bar{b}_2 = \frac{37}{6} = 6.2$$

$$\bar{b}_0 - \bar{b}_1 = 14 - 11.2 = 2.8* \qquad \bar{b}_0 - \bar{b}_2 = 14 - 6.2 = 7.8* \qquad \bar{b}_1 - \bar{b}_2 = 11.2 - 6.2 = 5*$$

$$\overline{a_0 b_0} = \frac{\sum a_0 b_0}{r} = \frac{46}{3} = 15.3 \qquad \overline{a_1 b_0} = \frac{38}{3} = 12.7 \qquad \overline{a_0 b_1} = \frac{33}{3} = 11$$

$$\overline{a_1 b_1} = \frac{34}{3} = 11.3 \qquad \overline{a_0 b_2} = \frac{27}{3} = 9 \qquad \overline{a_1 b_2} = \frac{10}{3} = 3.3$$

$$arrange: \overline{a_0 b_0} = 15.3 \qquad \overline{a_1 b_0} = 12.7 \qquad \overline{a_1 b_1} = 11.3 \qquad \overline{a_0 b_1} = 11$$

$$\overline{a_0 b_2} = 9 \qquad \overline{a_1 b_2} = 3.3$$

$$15.3 - 12.7 = 2.6^{n.s}$$

$$15.3 - 11.3 = 4^{*}$$

$$15.3 - 11 = 4.3^{*}$$

$$15.3 - 9 = 6.3^{*}$$

$$15.3 - 3.3 = 12^{*}$$

$$12.7 - 11.3 = 1.4^{n.s}$$

$$12.7 - 11 = 1.7^{n.s}$$

$$12.7 - 9 = 3.7^{*}$$

$$12.7 - 3.3 = 9.4^{*}$$

$$11.3 - 11 = 0.3^{n.s}$$

$$11.3 - 9 = 2.3^{n.s}$$

$$11.3 - 3.3 = 9^{*}$$

$11 - 9 = 2^{n.s}$ $\quad$ $11 - 3.3 = 7.7^{*}$ $\quad$ and $\quad$ $9 - 3.3 = 5.3^{*}$

$y_{ijk} = \mu + \mathbf{T}_{\mathbf{i}} + \varepsilon_{ijk}$ $\quad$ or $\quad$ $y_{ijk} = \mu + \mathbf{A}_{\mathbf{i}} + \mathbf{B}_{\mathbf{j}} + \mathbf{AB}_{\mathbf{ij}} + \varepsilon_{ijk}$

$i = 1,2$ $\quad$ $\mathrm{j} = 1,2,3$ $\quad$ $\mathrm{k} = 1,2,\ldots,18$

Q/ In an experiment you are given the following information, calculate the main , simple and the interaction effects ::

	a_1	a_2	Simple effect
b_1	5	7	5-7=-2
b_2	8	4	8-4=4
Simple effect	5-8=-3	7-4=3	

$$\text{Main effect (A)}=\frac{(5-7)+(8-4)}{2}=2/2=1$$

$$\text{Main effect (B)}=\frac{(5-8)+(7-4)}{2}=0/2=0$$

$$\text{Interaction effect (AB)}=\frac{(5-7)-(8-4)}{2}=-6/2=-3$$

$$\text{Interaction effect (BA)}=\frac{(5-8)-(7-4)}{2}=-6/2=-3$$

Q/ From the scheme below construct the ANOVA table and compare between the treatment combinations using Duncan's test (0.05).

Block 1	
a1b2	3
a1b1	4
a2b2	2
a1b3	5
a3b1	2
a2b1	1
a3b3	4
a3b2	3
a2b3	4

Block 2	
a3b2	4
a3b1	5
a2b2	2
a3b3	3
a1b1	2
a2b3	4
a1b3	5
a1b2	3
a2b1	5

Block 3	
a2b2	1
a1b1	2
a1b2	3
a2b3	2
a3b1	1
a2b1	4
a3b2	5
a3b3	3
a1b3	3

		Block 1	*Block 2*	*Block 3*	∑ *T.C.*
a1	**b1**	1	4	2	**∑ a1b1=7**
	b2	3	3	3	**∑ a1b2=9**
	b3	2	2	2	**∑ a1b3=6**
a2	**b1**	4	5	6	**∑ a2b1=15**
	b2	5	3	4	**∑ a2b2=12**
	b3	2	4	2	**∑ a2b3=8**
a3	**b1**	1	5	1	**∑ a3b1=7**
	b2	3	1	3	**∑ a3b2=7**
	b3	4	2	3	**∑ a3b3=9**
		∑ =25	**∑ =29**	**∑ =26**	***G*=80**

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.05}$
Block	3-1=2				3.63
T.C.	(3*3)-1=8				2.59
A	3-1=2				3.63
B	3-1=2				3.63
AB	4				3.01
Error	8*2=16				
Total	(3*3*3)-1=26				

Q/ A factorial LSD experiment was conducted (A FACTOR with 3 levels and B with 4 levels), mention:

1- The no. of T.C.=ab=? =12

2- No. of exp. Units=? =144

3- Statistical model=?

$$y_{ijkl} = \mu + \mathbf{A}_{\mathbf{i}} + \mathbf{B}_{\mathbf{j}} + \mathbf{AB}_{\mathbf{ij}} + R_k + C_l + \varepsilon_{ijkl}$$

$$i = 1,...,3 \qquad \mathrm{j} = 1,...,4 \qquad \mathrm{k} = 1,...,12 \qquad \mathrm{l} = 1,...,12$$

4- Sources of variation and degrees of freedom=?

df T.C. =ab-1=11

df A=a-1=2

df B=b-1=3

df AB=(a-1)(b-1)=6

df row=ab-1=11

df col.= ab-1=11

df error=(ab-1)(ab-2)=110

df Total= $(ab)^2$-1=143

❖ *Split Plot Design*

Q/ to test the effect of