University of Salahaddin
College of Agricultural Engineering Sciences
Dept. of Soil and Water

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3rd year Students
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Experimental Design and Analysis

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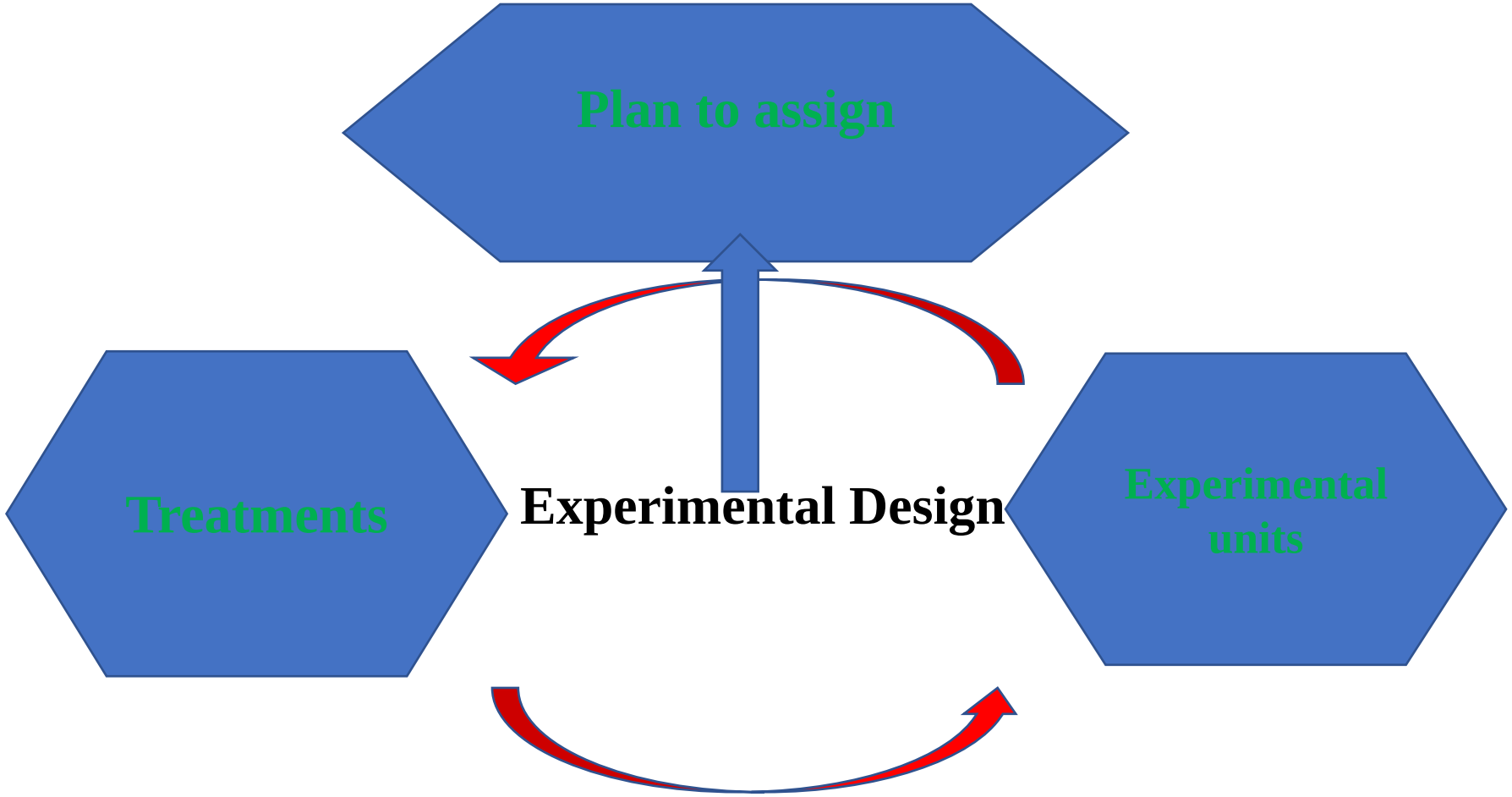
Definition of experimental design:

It a part of biostatistics which refers to a plan for assigning subjects (treatment) to experimental condition and the statistical analysis associated with the plan.



The experimental design involves the following steps :

1- Formulation of a statistical hypothesis
2- Determination of independent variable (X) experimental conditions) to be used, the measuring or recording dependent variable (y).
3- limiting the requirements.
4- Selecting the suitable design for conducting the experiment.
5- Statistical analysis using suitable test

Basic terms in experimental design:

1- **Treatment** it is a condition under the control of the researcher like temp., moisture, amount of growth media…etc

2- **Experimental unit**: it is a smallest part in experiment which receives a treatment. Experimental unit may be human, small animal, large animal, pots, plant, Petri dish, tree……etc.

3- **Simple experiment**: it is an experiment which includes one factor like studying four levels of temp. on the number of bacteria the factor is temp.

4- **Factorial experiment**: it is an experiment which includes two factors or more.

5- **Replicate**: Each experiment unit per treatment is a replicate

6- **Observation**: the experiment unit may be includes one observation or more for example one experiment unit may be includes two or more observations.

Principles of experimental design:

The Principles of experimental design includes:

1- Randomization. 2- Replication. 3-Local control

Functions of randomization:

The most important functions of randomization are:

1- To eliminate the effect of bias.

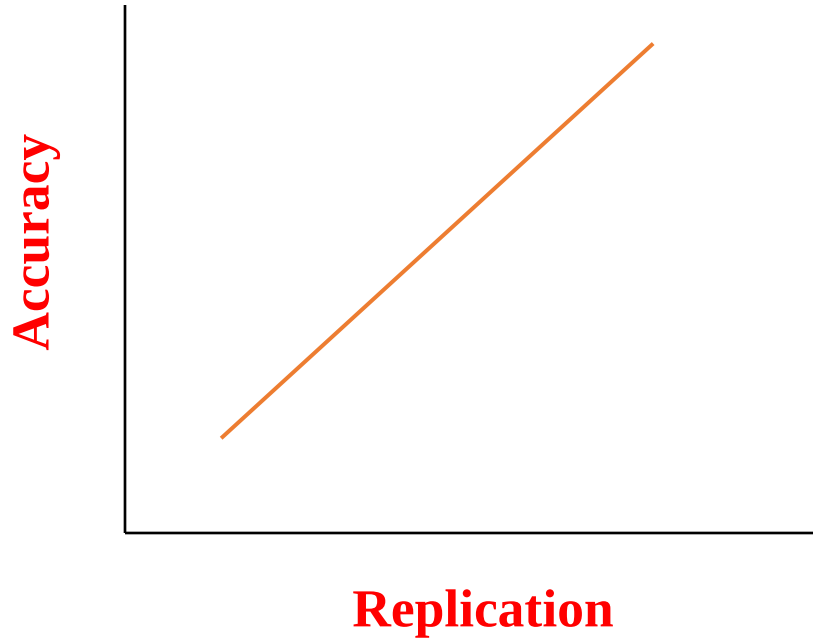
2-Protection from unusual events.

3- Error associate with adjacent experimental units are removed by randomization

Functions of replication:

The function of replication is to reduce standard error (SE) or increasing accuracy of data or experiments.

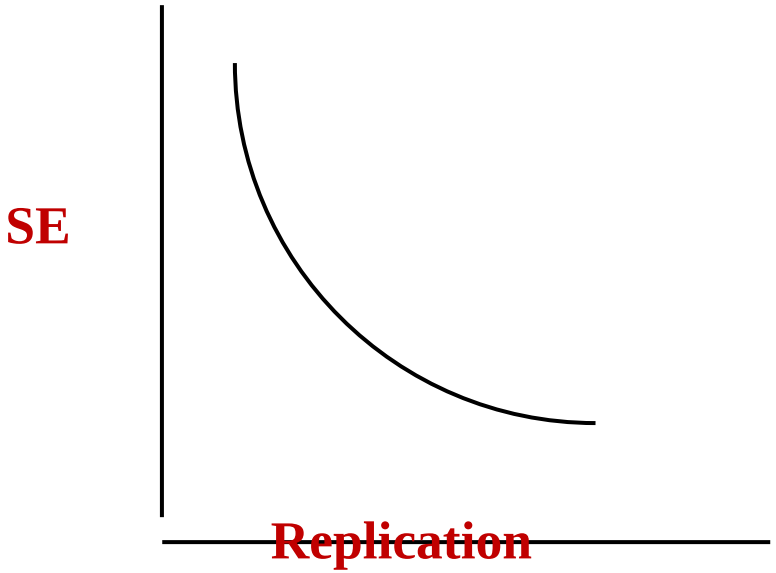
Increase in replication causes increase in accuracy .



Why?

Because increase increase in replication causes decrease in standard error (SX^-)

$$sx^- = \sqrt{\frac{S^2}{n}} = \frac{S}{\sqrt{n}}$$



Classification of experimental designs:

In general the experimental designs can be divided in to two classes: 1- systematic nature designs as shown from the schemes below:

B	C	A
B	C	A
B	C	A
B	C	A
B	C	A
B	C	A

C	C	C	C	A	A	A	A	B	B	B	B

A	A	A	A
B	B	B	B
C	C	C	C

B	B	C	C	A	A
B	B	C	C	A	A

A,B,C= Treatments

2- Modern experimental design or (Random nature designs)

nature design: the following schemes represent some random design:

B	A	B
A	C	A
C	B	C
C	A	C
A	B	B
B	C	A

A	B	C	A
B	B	A	B
C	A	C	C

C	A	B	C	A	B	A	C	B	C	B	A

B	A	B	C	A	C
A	B	C	B	C	A

A,B,C= Treatments

Completely randomized design (CRD)

CRD: This Design can be use if environmental conditions are fairly uniform or experimental units are homogenous ,for this reason CRD can be use in :

1- Laboratory experiments.

2-Green house experiments.

3-Glass house experiments.

4-Pot experiments.

Advantages of CRD:-

1- It is very simple design

2- It is a flexible design or there are no any restriction on the number of treatments or replication.

3- Statistical analysis is very easy.

4- It is used in case of equal or unequal replication

5- The missing value does not affect on the statistical analysis.

Disadvantages:

The disadvantage of CRD can be summarized as follows:

1- The experimental units must be homogenous.

2- It is used in laboratory experiment green house experiments and pot experiments.

3- It can not be used in field experiments.

4- It is less accurate than other designs.

Construction or layout of CRD:

The following steps are including for layout CRD

1- Preparing the requirements of the experiment like treatments and experimental units….. etc.

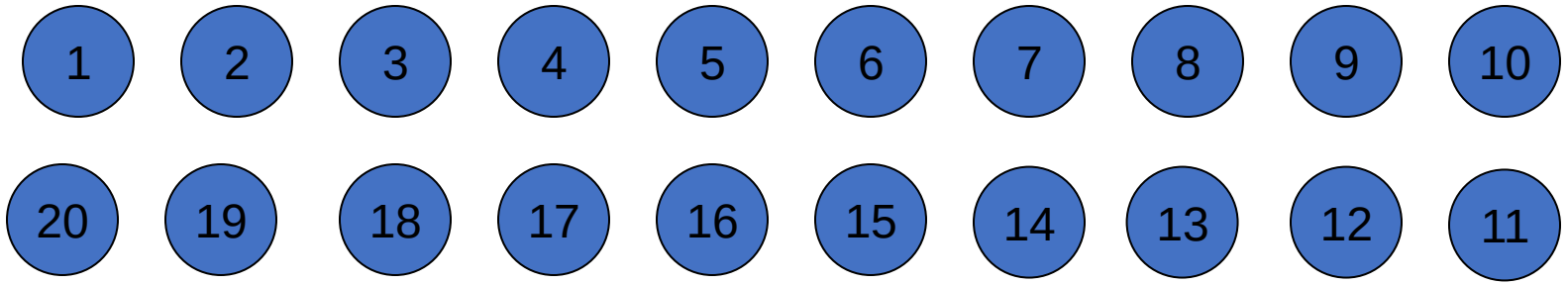
For example for studying the effect of 5 different temperatures (5, 10, 15, 20 and 25 C–) on growth radiuses (cm) of fungi using (4) replication.

N= 5*4=20 (Petri dishes) , because N= t*r , while

N= Number of experimental units , t = Number of treatments.

2- Number the experimental units from (1 to N) in a zigzag from.

3- Random assigning of experimental unit to treatments or assigning treatments randomly to experimental units as follow:



Statistical model:

$X_{ij} = \mu + T_i + E_{iJ}$

X_{ij}=value of any experimental unit.

μ = General mean . T_i = Treatment effect

i = from 1 to I th treatment)

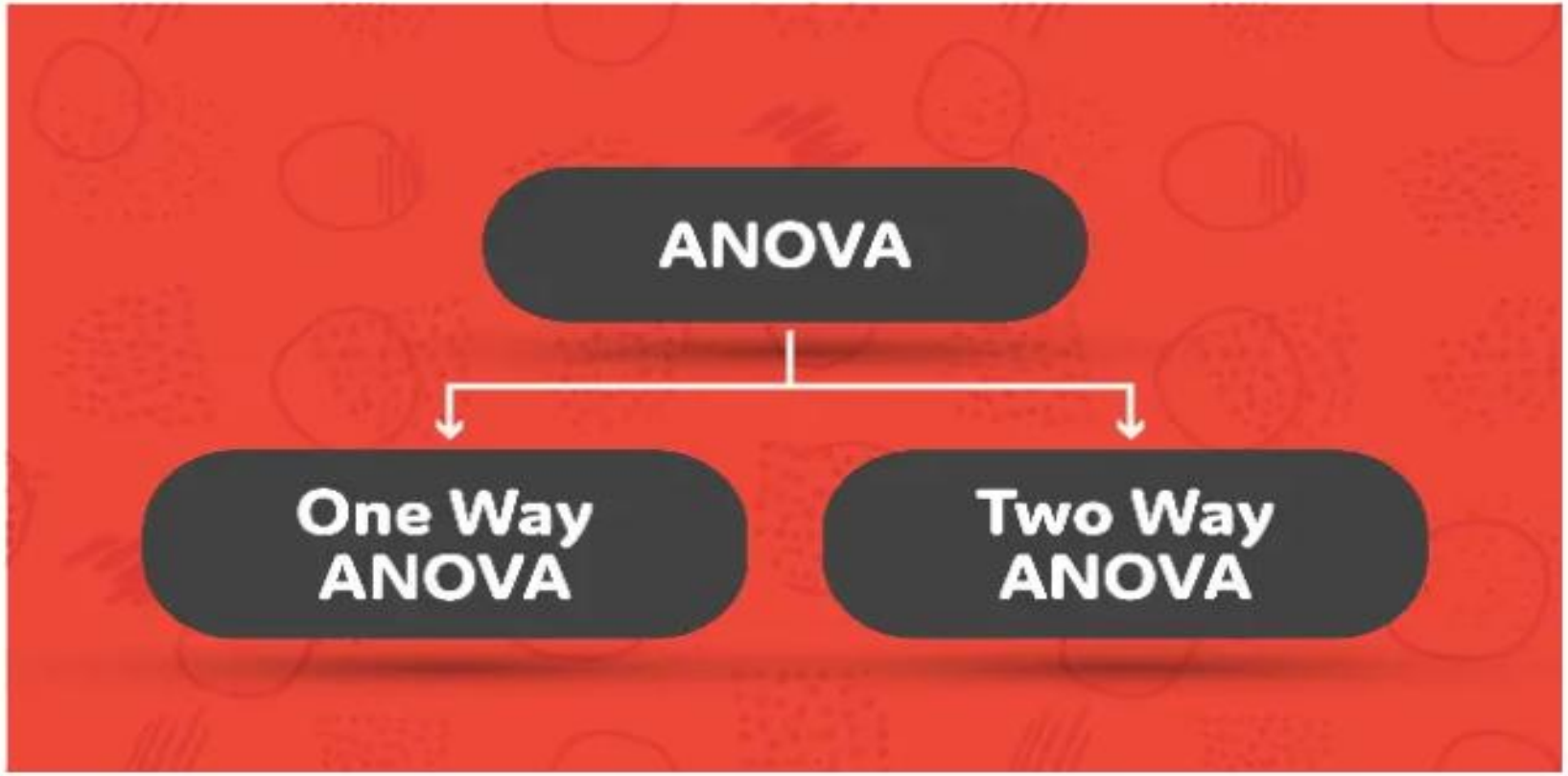
X_{ij}= the replications belong to a certain treatment.

In general the mathematical models can be divided in to two **models or types**: 1- Fixed effects model (Model I)
2- Random effects model (Model II)

Types of CRD:

1- CRD with equal replication.
2- CRD with unequal replication.
3- CRD with more than one observation.
4- Factorial CRD

Statistical analysis (ANOVA)Using SPSS program:



Equations

df = Degree of freedom

df t = t – 1 , df error = t (r – 1)

df total = n – 1 or [(t * r) – 1]

SS = Sum of square

Total SS = Σy^2_{ij} – C.F

C.F = Correlation factor

C.F = $(G)^2$ / t*r

Where:-G = summation of all values

n = number of experimental units

$$SSt = \frac{\sum t1^2 + \sum t2^2 + \sum t3^2 + \sum tn^2}{r} - C.F$$

Equations

SS error = SS total – SS t

Ms = mean square

Mst = SSt / dft

Mse = SSe / dfe

Calculate F

Cal. F = Mst / Mse

We compare Cal. F with tab. F, if cal. F is equal or greater than tab. F, it means that there was a significant difference between them, and vice versa.

Exp./ A green house experiment was conducted at *Plymouth university ,Faculty of Science and Environment* to test the effect of number of earthworm (0, 2, 4 and 8) earth worm/pot on nitrogen content (mg/g)of *Brassica rapi using* 3 replicates ,if you are given the following information , complete ANOVA table .

treats	r1	r2	r3	∑ treats
t1	2	3	4	9
t2	3	3	4	10
t3	4	3	4	11
t4	4	6	5	15

Total SS = $\Sigma y^2_{ij} - C.F$

$$\sum x^2_{ij} = 2^2 + 3^2 + 4^2 + \ldots + 4^2 + 5^2 - (45)2/3*4 = 181 - 168.75 = 12.25$$

$$SSt = \frac{\sum t1^2 + \sum t2^2 + \sum t3^2 + \sum t4^2}{r} - C.F$$

$$SS_{treat.} = \frac{9^2 + \ldots + \ldots. + 15^2}{3} - 168.75 = 6.91$$

SS_{Error}= Total SS – Treat.SS =12.25-6.91=5.34

Mst = SSt / dft =6.91/3=2.30

MSE = SSe / $d_{f\,E}$ =5.34/8=0.67

Cal.F=2.34/0.67=3.43

From special statistical tables we obtain:

Tab.$F_{(0.01,3,8)}$=7.59

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.01}$
Treatment	3	6.91	2.30	3.43 n.s	7.59
Error	8	5.34	0.67		
Total	11	12.25			

Since calculated F is less than Tab.F it means that there are no significance differences between treatments, or the earth worm not affected significantly on nitrogen content

Exp./ A green house experiment was conducted at *Plymouth university ,Faculty of Science and Environment* to test the effect of 4 species of earthworm on Nitrogen % of *Brassica rapi using* 3 replicates ,if you are given the following information , complete ANOVA table ,then test the significance of treatments.

treats	r1	r2	r3	∑ treats
t1	2	3	4	9
t2	3	3	4	10
t3	4	2	5	11
t4	7	6	7	20

$$\text{Total SS} = \Sigma y^2_{ij} - \text{C.F}$$

$$\sum x^2_{ij} = 2^2 + 3^2 + 4^2 + \ldots + 5^2 + 7^2 - (50)2/3*4 = 242 - 208.33 = 33.67$$

$$= 242 - (2500/12) = 242 - 208.33 = 33.67$$

$$SSt = \frac{\sum t1^2 + \sum t2^2 + \sum t3^2 + \sum t4^2}{r} - C.F$$

$$SS_{treat.} = \frac{9^2 + \ldots + \ldots + 20^2}{3} - 208.33 = (702/3) - 208.33 = 25.67$$

SS_{Error}= Total SS – Treat.SS =33.67-25.67=8.00

Mst = SSt / dft

=25.67/3=8.56

MSE = SSe / $d_{f\,E}$

=8/8=1

Cal.F=8/1=8

From special statistical tables we obtain:

Tab.$F_{(0.01,3,8)}$=7.59

S.O.V.	df	SS	MS	Cal.F	Tab.$F_{0.01}$
Treatment	3	25.67	8.56	8.56**	7.59
Error	8	8	1.00		
Total	11	33.67			

Since calculated F is more than Tab.F it means that there are significance differences between treatments, or the earth worm affected significantly on nitrogen content

Home work :

Example: A green house experiment was conducted at *Plymouth university ,Faculty of Science and Environment* to test the effect of number of earthworm (0, 2, 4 and 8) earth worm/pot on leaf area (cm^2)of *Brassica rapi using* 5 replicates ,if you are given the following information , complete ANOVA table ,then test the significance effect of earthworm on leaf area value.

Earthworm density	r_1	r_2	r_3	r4	r_5
t_1 =0	60	65	70	75	80
t_2 =2	80	90	70	85	75
t_3 =4	90	100	100	112	96
t_4 =8	110	112	120	121	114

Homework :

Example: A green house experiment was conducted at *Plymouth university ,Faculty of Science and Environment* to test the effect of 4 species of earthworm (*Aporrecodea spp.) o*n number of leaves /plant (*Brassica rapi)using* 5 replicates ,if you are given the following information , complete ANOVA table ,then test the significance effect of earthworm species on number of leaves at L.S =0.01.

Earthworm density	r_1	r_2	r_3	r4	r_5
t_1 = control	3	4	5	5	3
t_2 =*A. rosea*	5	5	6	5	7
t_3=*A.chlorotica*	7	8	7	8	9
t_4 =*A. caliginosa*	15	15	13	15	14

Example ./ The Green house experiment was done at Plymouth university to study the effect of 5 species of earth worm on nitrogen concentration (mg/g dry matter of plant , Complete ANOVA table .

Treatments	r_1	r_2	r_3	r_4	*Σ of t*
t_1	12.3	13.1	12.9	13.2	51.5
t_2	14.6	15.5	13.5	14.2	57.8
t_3	13.5	14.6	13.8		31.9
t_4	12.9	13.0	14.0	14.0	53.9
t_5	13.9	12.8	13.7		40.4
					G=235.5

No. of exp. Units (n) = Σri =4+4+3+4+3=18

df_t= t-1=4 and df_t = Σri -1=18-1=17

C.F. =$(235.5)^2/18$=3081.125

SST=[$(12.3)^2+(13.1)^2+\ldots+(13.7)^2$ – **3081.125 =**10.50

$$SSt = \frac{\sum t1^2}{r_1} + \frac{\sum t2^2}{r_2} + \frac{\sum t3^2}{r_3} + - - - + \frac{\sum t5^2}{r_5} - C.F$$

$$SS_t = \frac{(51.5)^2}{4} + \frac{(57.8)^2}{4} + \frac{(31.9)^2}{3} + \frac{(53.9)^2}{4} + \frac{(40.4)^2}{3} - 3081.125$$

$$= 5.48$$

$$SS_E = SSTotal - SStreat = 10.5 - 5.48 = 5.02$$

ANOVA Table

S.O.V.	df	SS	MS	Cal.F	Tab.F
Treatment	4	5.48	1.37	$3.51^{n.s}$	$5.205_{(0.01)}$
Error	13	5.02	0.39		
Total	17	10. 5			

Home work: The study was conducted to test the effect of [5]levels of iron on number of active nodules/plant ,complete ANOVA table if you are given the following information ,then compare between treatments using $LSD_{0.01}$ and DMRT：

Treatments	r1	r2	r3	r4
t_1=0 mg/pot	4	5	4	6
t_2=2 mg/pot	5	7	7	8
t_3= 4mg/pot	6	7	9	9
t_4=6 mg/pot	10	12	14	14
t_5=8 mg/pot	7	8	8	9

A study was conducted to study the effect of 6 specie of Rhizobium ,on weight of active nodules/plant using 4 replicates. Complete .ANOVA table then compare between treatments using different tests

treats	r_1	r_2	r_3	r_4
t_1	7	8	7	6
t_2	6	5	6	5
t_3	4	4	3	4
t_4	3	3	3	2
t_5	2	1	1	1
t_6	1	2	2	1