FWM 310: FOREST BIOMETRICS

LECTURE NOTE

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FOREST BIOMETRICS: FWM 310

DESIGN AND ANALYSIS OF EXPERIMENT

Expel design and sample design.

Sample design is a method of choosing the required number of sample in a given population. Exptal design is where identical or difficult subject.

An experimental unit is a unit of difference subject of the treatment is applied and he treatment is the factor whose effect is to be investigated or measured and compared the other treatment.

Experimental error is one of the most important in an experiment it is a variation among unit of experiment alike it is a measure of variation each exist among observation of experiment issue treated alike.

There are 2 main source of variation

1. Inherent variation that exist in the experimental material to each treatment are applied
2. Variation which result from lack of uniformity in the physical conduct of experiment e.g. unequal instrument unit. Like experimental error based on this sources of variation can thus be reduced by

1. Handling the experimental materials so that the effects of inherent error may be reduced.
2. Refusing experimental techniques

CRD

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

A B C D

0% 10% 15% 20%

RCB --- introduce blocking so as to reduce the variation by randomization. The important thing is that within each block all of them have to be represented. There is no block where you have two treatments.

CRD

Model: $y_{ij} = \mu + T_j + \Sigma_{ij}$

A_4	C_2	A_7	C_2	B_4
D_4	B_6	B_5	D_1	A_2
C_4	B_7	E_3	D_6	E_3
A_3	C_5	E_2	C_3	E_4
D_5	D_4	A_5	C_4	B_5

replicate í, 1, 5

Treatment j, 1, 5

SS total = $\Sigma y_{ij}^2 - CF = 4^2 + 2^2 \ldots\ldots 25^2 - CF$

Ss Treatment $\Sigma y_{.j}^2/r^2$ CF = 473 – 416.16 = 56.862

$$= \frac{27^2 + 27^2 + 17^2 + 28^2 - CF}{5}$$

= 421.8 – 418.18 = 5.64

Error Ss = Total ss – Treatment ss

= 56.84 – 5.64 = 51.20

ANOVA TABLE

Source of variation	df	Ss	ms	F mst
Treatment	4	5.64	1.41	MSE
Error	20	51.20	2.5	0.564
Total	24	56.4		

$F_{0.5}$ (4, 20) = 2.87

$F_{0.1}$ (4, 20) = 4.43

F, calculated of 0.564 is < F tab of 2.87 at 5% probability level it means they there is no significant difference between the treatment i.e Treatment ABCDE are identical/there is no significant difficult in their effect of the fertilizer level. Therefore any of the treatment can be adopted.

RCB

Model = yij = μ + Tj + Bi + Eij

ANOVA TABLE

Source of variation	df	Ss	ms	F
Treatment	4	13.76	3.44	1.98
Block	4	22.16	5.54	3.04
Error	16	29.04	1.0	
Total	24	64.96		

Total = 25

Treatment = 5

Block = 5

F cal treatment = 1.89

F cal block = 3.04

F cal treatment has no significant different between treatment

F cal block has different between the block

Thus blocking is very significant important because it bring differences in the yield/block

LATIN SQUARE (3 way)

Ls =

Model = yijk = μ + Ri Cj + Tk + Eijk

Source of variation	df	Ss	ms	F mst
Row	r-1 = 4	75.57	18.39	1.61
Column	r-1 = 4	583.51	145.89	13.12
Treatment	r-1 = 4	67.86	16.97	1.53
Error	(r-1)(r-2) 12	133.35	11.20	
Total	24			

F0.5 (4, 12) = 3.26

I	II	III	IV	V	
A	B	C	D	E	1
B	C	D	E	A	2
C	D	E	A	B	3
D	E	A	B	C	4
E	A	B	C	D	5

A B C D

A C B D

B C D A

B C D A

Tj BK

Even with the RCD there is still a problem, to solve this you introduce Latin square. Therefore the number of treatment must be equal to he number of row and the number of column must be equal to the number of treatment.

B C A D

C A D B

A D B C

D B C A

Tj Rk Cm

CRD can be used in comparison of two or more groups of treatment by one way analysis of variance (ANOVA). Anova is an arithmetic process for partitioning a total sum of square into components. CRD is useful when experimental units are homogenous.

CRD

A A B C

D B B D

A C C D

A B C D

RCB

A B C D

A C B D

B C A D

D C A B

A B C D

B C D A

C D A B

D A B C

Significant difference

A α B

A α C

A α D

B α C

B α D

C α D

LAEST SIGNIFICANT DIFFERENCE (LSD)

This is to further find out the significant difference between at least 2 treatment. It is he option after our

1. F is significant
2. The number of treatment must not be more than 5
3. The experiment must be a control experiment and in effect get the difference between the control and other treatment. Relax the 2nd condition if it is a control experiment.

DMRT Rice Yield mean d

bc	A	2537	2069	2104	1797	2127
a	B	3366	2591	2211	2544	2678
ab	C	2536	2459	2827	2385	2552
bc	D	2387	2453	1556	2116	2120
C	E	1997	1679	1649	1859	1796
Cd	F	1796	1704	1904	13020	1681
d	G	1407	1516	1270	1071	1316

ANOVA TABLE

Source of variation	df	Ss	ms	F
Treatment	6	5.58m	931,196	9.82
Error	21	1.99m	94,773	
Total	27	7.57m		

F0.05 (6, 21) 2.57

F0.01 (6, 21) 3.81

Because the F cal is > F tab, there is a significant difference

LSD $\alpha = t\ \alpha \sqrt{2S^2/r}$

S^2 + error ms

Tα = F tab at dt level

r = number of replicate

LSD 0.05 = t0.05 (6, 21) = 2.08

$= 2.080 \times \sqrt{\frac{2 \times 94,773}{4}} = 453$

LSD 0.01 = 2.831 X $\sqrt{2 \times 94,773}$ = 616

4

Calculating difference ‘d’ i.e M-the control mean

	d	
A	811	
B	1362	
C	1236	
D	812	
E	480	
F	365	N.S at 0.05

We now compared the d of each weigh the LSD 0.05 and LSD 0.01

LSD 0.05 = 453 is significant with A-E

LSD 0.01 = 616 only 4 of the treatments are significant

Conclusion

DMRT: Dunean Multiple Ratio Test

For the above experiment

	Sort			R	P	rp0.05	rp0.01	Rp(SrSxp)
B	2678	a		1	2	2.943	4.024	452.6
C	2552	a	b	2	3	3.09	4.197	475.6
D	2128	b	c	3	4	3.18	4.312	489.5
A	2127	b	c	4	5	3.25	4.395	500.3
E	1796		c	5	6	3.30	4.495	507.97
F	1681		c	6	7	3.33	4.510	512.6

G 1361 d 7

Calculate SE = SX = $\sqrt{\frac{S^2_{xy}}{n}}$ = $\sqrt{\frac{23777.8}{7}}$ = 153.93

Shortest significant range

RP = rpSX

(1) 2678 – 512.6 = 2165

(2) 2552 – 508 = 2044

(3) 2128 – 500 = 1628

MSTATIC Statistic package: Group the treatment mean in decreasing order for the largest mean, subtract the shortest range of the highest P. Declare all means less than these significantly difference from the largest mean because it is only B and C that fall in these category it means they are similar that is, not significant.

Quick check is to subtract between 2 sot value and compare it with RP of the value between the 2, say B and C ----- 2678 – 2552 = 126 compare < RP of 2 ------- 452.6 since 126 < 452.6. There is no significant difference between B and C

A and G = 2127 – 1316 = 811 > R4 there is significant difference

A and G = 1796 – 1316 = 480> R3 there is significant difference

F and G = 1681 – 1316 = 365 < R2 they are similar

AB	NS
AC	#
AD	#
AD	#
AE	#
F	#

AG NS

Diversity and similarity indices

This is an applied statistics

To measure the diversity of the species we can use (1) swimpson diversity index Σpi

$$\frac{\Sigma ni(ni-1)}{N(N-1)} \quad \Sigma pí$$

Eg	Zone 1	Zone 2
A	20	15
B	-	10
C	15	25
D	10	-
E	13	15
	4	4
	60	65

$$= \frac{\Sigma ni\ (ni-1)}{N(N-1)}$$

$$= \frac{(20 \times 19) + (15 \times 14) + (10 \times 9) + (15 \times 14)}{60 \times 59}$$

$$= 0.25$$

$$\frac{(15 \times 14) + (10 \times 9) + (25 \times 24) + (15 \times 14)}{65 \times 64}$$

$$= 0.27$$

The higher the value the lower the diversity

Zone 1 is none diversity than zone 2

1/0.25 = 4

1/0.27 = 37

The diversity of swingson formular can be used

$$= \frac{N(N-1)}{\Sigma n(n-1)}$$

$\Sigma pi = (20/20)^2 + (15/60)^2 + (10/60)^2 + (15/60)^2$

$=0.33^2 + 0.25^2 + 0.11^2 + 0.25^2$

Shamon index = H

i $= -\Sigma (ni/N) \log_e (ni/N)$

ii $\Sigma pi \log_e pi$

we can calculate eveness from the above

Eveness = $H/\log_e S$

S = number of species.

Similarity indices

Sorenson's similarity index

$$\frac{a}{a + b + c} \times 100$$

a = number of species common to both

b = number of species in site 1 but not in site 2

c = number of species in site 2 but not in site 2

3/3+1+1 x 100 = 3/5 x 100 = 60%

Sinpson similarity index = $\frac{a}{\text{Min } (a+b)\ (a + c)}$

$$\frac{3}{\text{Min } 14, 4} = ¾ \times 100 = 75\%$$

Sorrenson similarity can be used when one is sure that the sampling unit is the same e.g. when Zn 1 has 2 plots, Zn 2 has 3 plots e.t.c. siorrenson can not be used but swinmpson sin index can be used

A	20	15	5
B	-	10	-
C	15	25	-
D	10	-	20
E	15	15	5
F	10	5	-
G	2	-	4
H	3	-	-

Simpson sin index

$$= \frac{a}{\min (a+b)(a+c)}$$

a = 4

b = 3

c = 1

$$\text{simpson} = \frac{4}{7,5}$$

1 and 2 = 4/5 = 80%

1 and 3 = 4/7,4 = 4/4 = 100%

b = 3

c = 0

2 and 3 = a = 2

b = 3

c = 2

2/5,4 = 2/4 = 50%

DESIGN AND ANALYSIS OF EXPERIMENTS

INTRODUCTION

An expert is a research tool used to discover something unknown or to test a principle of hypothesis. In other words, an expert is a planned inquiry to obtain new fact or to confirm or deny the results of previous experiments of the existing belief such that the inquiry will aid in making decision or recommendation.

TYPES OF EXPERTS

Experts can be broadly classified into two categories, namely absolute experts and comparative experts. The latter is conducted with the full aim of comparing the effects of several conditions on some phenomenon e.g. an experts may be conducted to determine the effects of some fertilizers on the growth rate of *Tectona grandis* while in absolute experts, the sole aim si to discover a new information which will either confirm or contradict an existing belief.

Experts in forestry and wildlife or nay other field, produce results which form the basis for making decisions. A forest pathologist may decide to apply a new fungicide on his nursery based on the reports from researchers that the fungicide is effective. In view of this, many important decisions are made based on the results of experts, it is of paramount importance, therefore, that experts, are well planned so as to produce valid results. Through careful planning and conduct of an experts, data are acquired which are then analyzed and interpreted with respect to the objectives of the experts.

The complete sequence of steps taken ahead of time to insure that the appropriate data will be obtained in a way that permits an objective analysis leading to valid inferences is referred to as the Experimental Design.

PROCEDURE FOR EXPERIMENTATION

The procedure for experimentation is usually determined by the nature of the experimentation and the objective of the study. The procedure t follow include:

i. Define the problem: Every research begins with the identification of an existing problem which the researcher can reasonably hope to solve.
ii. State your objective: The objective of the experimentation should be clearly stated. The objective may be in the form of question to be answered, the hypothesis to be tested or the effects to be estimated. The statement of objective should include an account of the

area over which generalization are to be made or the population about which inferences are to be made.

iii. Plan the experimentation: The experimentation should be planned with a view to achieving the objective. At this stage, adequate consideration should be given to the experimental materials, the treatments, the variables of interest, the number of replicates, and the data to be collected. The experimenter also make an outline of the statistical analysis to be carried out as well as possible summary tables or graph to be drawn.

iv. Conduct the experimentation: The experimentation should be conducted carefully and objectively. It should be noted that no amount of statistical manipulation can make a bad experimentation give god results. The experimenter should, however, keep his mind open to the possibility of obtaining other useful information without prejudice to his main interest. The data collected at each stage of the experimentation should be clearly recorded and properly documented. The design must be kept as simple as possible. Efforts should be made to conserve time, money, personnel and experimental materials. The scope of the experimentation should be large enough to provide a wide basis for inductive inference.

v. Analyze the data and interpret the results: Care should be taken to avoid mistakes in copying data from the field note books. All calculations should be carefully checked. Simple tables and diagrams should be used when summarizing the results of statistical analysis. Correct decisions should be made concerning the hypotheses, and the interpretation of the results should be done in terms of the subject matter.

vi. Prepare a complete, readable and correct report of the research: The report must tell the truth and must contain all the important information necessary for someone else to repeat

the experimentation. The report must also meet standards in the scheme, arrangement, the tables, figures, nomenclature and bibliography.

COMMON TERM IN EXPERIMENTAL DESIGN

1) Treatment: This is a term used for any particular set of experimental conditions that will be imposed on an experimental unit within the confines of the chosen design e.g. an experimentation may be conducted to determine the effect of depth of seeding on the yield growth of *Gmelina arborea*. The several depths of seeding constitute effects of two experimental conclusions such as temperature and humidity, amount of fertilizer and depth of sowing are examined in an experimentation. Such treatment combined treatments are called treatment combinations.
2) Experimental unit: This refers to that material to which a single treatment is applied in one replication of the basic experimentation e.g. a plot of land, a batch of seeds, a group of animals etc.
3) Experimental error: This is a measure of the variation which exists among observations on experimental units treated alike. It describes the failure of the identically treated experimental units to yield identical results. Experimental error reflects.
    - The errors of experimentation, observation and measurements
    - The variation among experimental units, and
    - The combined effects of all extraneous factors that could influence the characteristics under study but have not been singled out for attention in the current investigation.

Experimental error affects the accuracy of experimentations, and therefore the methods of reducing it are also means of increasing the accuracy of experimentations. Experimental error can be reduced in the following ways:

a) Reducing the effects of inherent variability in the experimental material. This may be accomplished by

- Using more homogenous experimental material
- Taking additional measurements that provide more information on the experimental material
- Using information provided by related varieties
- Grouping the experimental units skillfully such that the units to which one treatment is applied are closely comparable with those to which another treatment is applied.

b) Increasing the size of the experimentation either through the provision of more replicates or by the inclusion of additional treatments.

c) Using more care in conducting the experimentation

d) Using a more efficient experimental design.

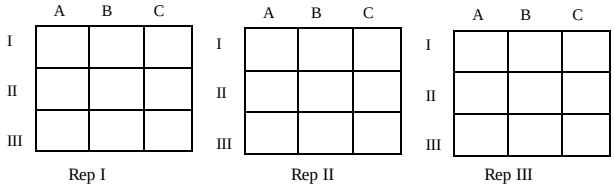
BASIC PRINCIPLES OF EXPERIMENTAL DESIGN

There are three basic principles of experimental design namely randomization, replication and local control.

1) Randomization: This is a process by which the allocation of treatments to experimental units are done by means of some chance device. It ensures that treatments will not be continually favoured or handicapped in successive replications by extraneous sources of variation known as unknown. Thus, it assist in 'averaging out' the effects of extraneous factors that may or may not be present. The function of randomization is to ensure that

the experimenter has a valid or unbiased estimate of experimental error. Apart from random designs, there are also non-random but selected fashion. The use of these designs makes it impossible to attach an unbiased measure of reliability to the inferences made. Systematic designs result in either underestimation or overestimation of experimental error, as well as inequality of precision in the various comparisons among the treatment means.

2) Replication: It refers to the repetition of the basic experimentation e.g. in testing the effects of three fertilizer on the growth of three tree species with three replication. The lay-out is as follows:



When a treatment appears more than once in an experimentation, it is said to be replicated. Multiple reading for a treatment appearing once do not necessary represent true replication. In other word, repeat measurement on the same experimental unit is not true replication. When each treatment appears only once in an experimentation, the experimentation is said to consist of a single replication or replicate. For such an experimentation, experimental error. Thus the observed differences could be explained as differences between the treatments or between the experimental units i.e. it cannot be determined whether observed differences indicate true differences or are due to inherent variation.

The functions of replication can be summarized as follows:

- It provides an estimate of the experimental error which serves as the basic unit of measurement for assess in the significance of observed differences or for determining the length of a confidence interval.
- It improves the precision of an experimentation by reducing the standard deviation of a treatment mean.
- It increases the scope of inference of the experimentation by selection and appropriate use of more variable experimental unit.

However, the number of replicates for any experimentation depends on the degree of precision required, the experimental design the number of treatments, the degree of variation in the experimental units, and fund and time available for the experimentation.

3) Local control: It refers to the amount of grouping, blocking and balancing of the experimental unit that is employed in the adopted statistical design. It makes the experimental design more efficient i.e. it makes the test of significance more sensitive.

This is because the magnitude of the estimate of experimental error is reduced by proper use of local control.

- Grouping: It means placing a set of homogenous experimental units into groups in order that different treatments are applied to the different groups. The groups may even have different number of experimental units.
- Blocking: It means allocating the experimental units into blocks such that the units within a block are relatively homogenous while the units between the blocks are heterogeneous. In this case, all the treatments are applied within each block.
- Balancing: it is by obtaining the experimental units, the grouping, the blocking and the assignment of treatments to the units in such a way that a balance configuration results.

GENERAL LINEAR HYPOTHESES

STEPS IN DESIGNING AN EXPERIMENTAL

- Name the design
- State the statistical model
- State the assumptions
- Present the lay-out
- State the hypotheses i.e. tests of significance
- Do the estimation
- Draw inferences and make relevant conclusions

REFERS TO SINGLE FACTOR EXPERIMENTATIONS

COMPLETELY RANDOMIZED DESIGN (CRD) ONE WAY CLASSIFICATION

It is a design in which the treatments are allotted completely at random to the experimental units. Thus, every experimental unit has the same probability of receiving any treatment without any restriction. The design is useful only when the experimental units are essential homogenous e.g. given 4 fertilizers A, B, C, and D with which to test the H_0 that there are no differences among the effects of these fertilizers on the volume of wood produced by *Gmelina arborea*.let us further assume that there are 20 experimental plots available for the research. A good design method will place each fertilizer on an equal number of plots so that over estimate of mean effects fertilizer will have equal weight. We also insist that the fertilizers be assigned to the plots at random using table of random numbers or any random process.

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

ADVANTAGES OF THE CRD

- It is flexible in that any number of treatments and of replicates may be used
- The statistical analysis is simple even if the number of replicate varies with the treatments
- Simplicity of analysis is not lost if some experimental unit or entire treatments are missing or rejected
- The number of degrees of freedom for estimating experimental error is maximum.

DISADVANTAGES OF THE CRD

Since randomization is unrestricted, experimental error includes the entire variation among the experimental units except that due to treatments. In situations where there are variations among the units, CRD is inefficient.

1) Name of design: Completely randomized design (CRD)
2) Model: $Y_{ij} = \mu + t_j + e_{ij}$

   Where:

   Y_{ij} = Individual observation i.e. observation of j_{th} treatment in i_{th} plot

   μ = General mean i.e. the population mean of all possible similar experimentations

   t_j = Effect error containing all uncontrolled sources of variation.
3) Assumption: (I) The treatment effects are additive and fixed (no interaction) i.e.

   $\sum_{j=1}^{t} t_j = 0$

   (II) Experimental errors are randomly in independently and normally distributed above zero mean and with a common variance i.e. e_{ij} µ NID (0, 0^2).
4) Lay-out:

T_1	T_2	T_3	……	T_t
Treatment total $\sum T_1$	$\sum T_2$	$\sum T_3$		$\sum T_t$
Number of observation nT_1	nT_2	nT_3	……	nT_t
Treatment mean $\bar{T}_1$	$\bar{T}_2$	$\bar{T}_3$	……	$\bar{T}_t$

5) Hypotheses:

H_o – No significance treatment differences

H_A – There are significant treatment differences

6) Computation: Estimate the correction factor

$$C.F = \frac{(\text{Grand total})^2}{\text{Total number of observation}}$$

Total sum of square $(SS_{total}) = \sum Y_{ij}^2 - C.F$

Where $\sum Y_{ij}^2$ is the summation of the square of each observation

$$\text{Treatment sum of square } (SS_{trt}) = \frac{\sum T_1^2 + \sum T_2^2 + \ldots\ldots\ldots\ldots\ldots \sum T_t^2 - C.F}{\text{number of observation per treatment i.e. } nT}$$

Where $\sum T_1^2, \sum T_2^2 \ldots\ldots \sum T_t^2$ are the totals for treatments

$T_1, T_2 \ldots\ldots\ldots\ldots\ldots T_t$ respectively and $nT_1, nT_2 \ldots\ldots\ldots\ldots\ldots nT_t$ are the number of observations for treatment $T_1, T_2 \ldots\ldots\ldots\ldots\ldots T_t$ respectively.

error sum of square $(SS_E) = SS_{total} - SS_{treatment}$.

Degree of freedom (df)

- For total (df total) = Total number of observation – 1 or (r) (t) - 1
- For treatment (df treatments) = Number of treatments – 1 i.e. (t-1_
- Foor error (df error) = df total – df treatments or t(r-1)

Mean Squares (MS): These are obtained by dividing the SS treatments and SSerror by the df treatment and df error, respectively.

$$F - \text{Calculated (variance ratio)} = \frac{\text{MS treatments}}{\text{MS error}}$$

7) The analysis of variance table (ANOVA) table

Source of variation (S.V.)	Degrees of freedom (df)	Sum of squares (SS)	Mean squares (MS)	F-calculated
Treatments	T – 1	SS_{trt}	$SS_{trt}/t - 1$	MS_{trt}
Error	Df total – df trt	SS_E	SS_E/dferror	
Total	(r) (t) -1 n – 1	SS_{total}		

8) Inference and conclusion

The F-tabulated will be obtained from the table at desired α or Pr level and it is usually at 0.05 or 0.01 level of significance. Taking the degrees of freedom for treatment and error as V_1 and V_2 respectively, the F-tabulated i.e. $F(V_1, V_2)$ will be checked from the table at the desired probability level.

CONCLUSION

Where F-calculated is greater than F-tabulated, the H_o is rejected, thus it is concluded that there are significant treatment differences and vice-versa.

e.g. 4 spray treatments were applied completely at random in a teak plantation.24 sampled plots were used and the yields per plot were recorded as follows:

$S_1(5)$	$S_2(2)$	$S_4(8)$	$S_4(2)$
$S_3(5)$	$S_1(3)$	$S_2(2)$	$S_1(2)$
$S_2(4)$	$S_3(6)$	$S_1(5)$	$S_3(3)$
$S_1(5)$	$S_1(2)$	$S_2(6)$	$S_1(7)$
$S_9(9)$	$S_3(9)$	$S_3(8)$	$S_3(3)$
$S_4(4)$	$S_2(7)$	$S_2(6)$	$S_4(5)$

Test the H_o that there are no significant difference among the effect of these spray treatments on the yield of teak.

i. Name of design: CRD

ii. Model: $Y_{ij} = \mu + t_j + e_{ij}$

Define each

iii. Assumptions: State them as shown in previous note

iv. Lay out

	S_1	S_2	S_3	S_4
	5	4	5	9
	5	3	6	4
	3	7	9	8
	2	3	8	4
	2	6	3	2
	7	6	3	5
$\sum T$	24	29	34	32
n	6	6	6	6
$\bar{T}$	4	4.83	5.67	5.33

v. Hypotheses:

H_o – There is no significant difference among the effect of spray treatments

H_A – There is significant difference among the effect of spray treatments.

Compute the grand mean and the coefficient of variation curves

Grand mean = GT , CV = $\frac{\sqrt{MSE}}{\text{Grand Mean}} \times 100$

The CV indicates the degree of precision with which the treatments are compared and is a good under of the reliability of the experimental. It expressed the experimental error as percentage of the mean, thus, the higher

vi. Computation:

C.F. = $\frac{(GT)^2}{n}$ or $\frac{(\sum Y_{ij})^2}{n} = \frac{(5+5+3+\ldots\ldots+5)^2}{24} = \frac{(119)^2}{24}$

= 590.0417

SS_{total} = $\sum Y_{ij}^2 - C.F$

= $5^2 + 5^2 + 3^2 + \ldots\ldots\ldots\ldots\ldots 5^2 - 590.0417 = 110.9583$

SS_{trt} = $\frac{\sum T_i^2 - CF}{No\ of\ Obs/Trt} = \frac{24^2 + 29^2 + 34^2 + 32^2}{6} - 590.0417$

$= \frac{\sum T_i^2}{n} - 590.0417$

= 599.5 – 590.0417

SS_{error} = SS_{total} - SS_{trt}

= 110.9583 – 9.4583

= 101.5000

vii. ANOVA Table

SV	df	SS	MS	F
Treatment	3	9.4583	$\frac{9.4583}{3} = 3.1528$	$\frac{3.1528}{5.075} = 0.6212$
Error	20	101.5000	$\frac{101.500}{20} = 5.075$	3
Total	23	110.9583		

F-tabulated (i.e. $F(V_1, V_2)$

$F(3,20) = 3.10$ and 4.94 for 0.05 and 0.01

viii. Levels of significance, respectively:

Since the F-tabulated is greater than the F-calculated, the H_o is accepted. It is therefore concluded that there are no significant ($P<0.05$ or $P<0.01$) differences among the effects of the 4 spray treatments on the yield of Teak.

2) Forester conducted a preliminary study of the effects of 3 different sources of fertilizer on the growth rate of *Gmelina arborea* in the nursery. The results are as follows:

The CV volume, the lower is the reliability of the experimentation. The CV value is generally placed below the analysis of variance table.

S_1	S_2	S_3
8	11	12
7	10	12
8	10	13
9	9	9
	13	10
	12	12
	13	12

	9	18
		20

Are there difference in the effects of fertilizer sources?

i. Name of design:CRD with unequal number of observation per treatment.

ii. Model: $Y_{ij} = \mu + t_j + e_{ij}$

Define each

iii. Assumption: (i) Treatments effects are additive and fixed (i.e. no interaction) $\sum_{j=1}^{r} t_j = 0$

(ii) Experimental error are randomly, independently and normally distributed about zero mean and with a common variance i.e. e_{ij} μ NID $(0,\sigma^2)$

iv. Lay-out:

S_1	S_2	S_3
8	11	12
7	10	12
8	10	13
9	9	9
	13	10
	12	12
	13	12
	9	18

			20
			25
$\sum T$	32	87	143
n	4	8	10
$\bar{Y}$	8	10.875	14.3

v. Hypotheses:

H_o – There is no significant difference

H_A – There is significant difference

vi. Computation:

C.F. $= \frac{(\sum Y_{ij})^2}{n} = \frac{(362)^2}{22}$

= 3120.1818

SS_{total} = $\sum Y_{ij}^2 - C.F$

= $8^2 + 9^2 + \ldots\ldots\ldots\ldots 25^2 - 3120.1818$

= 3498 - 3120.1818

= 377.8182

SS_{trt} = $\frac{(\sum Y_1)^2}{n} + \frac{(\sum Y_2)^2}{n} + \frac{(\sum Y_3)^2}{n} - C.F$ =

$\left(\frac{(32)^2}{4} + \frac{(87)^2}{8} + \frac{(143)^2}{10}\right) - 3120.1818$

= 32470.25 – 3120.1818

= 126.8435

SS_{error} = SS_{total} - SS_{trt}

= 377.8182 – 126.8435

= 250.975

vii. ANOVA Table

SV	df	SS	MS	F
Treatment	2	126.8435	63.4218	4.8013
Error	19	250.975	13.2092	
Total	21	377.1882		

F-tabulated (i.e. $F(V_1, V_2)$

F(2,19) = 3.52 and 4.94 at 0.05

F(2,19) = 5.93 and 4.94 at 0.01

Since the F-calculated is greater than the F-tabulated at either 0.05 or 0.01 level of significance, the null hypothesis is not accepted i.e. rejected. It is therefore concluded that there are significant ($P<0.05$) differences in the effects of the sources of fertilizer on the growth rate of *Gmelina arborea* or in the effects of the fertilizer treatments. If 0.01 level of significance is used, then the conclusion will be that there are highly significance ($P<0.01$) differences in th effects of the fertilizer treatments.

HOMEWORK

Members of African Giant rat (*Cricetomys gambianus*, Waterhouse) colony were fed with diets A, B, C and D. the purpose of the study was to determine which diet enehances the growth of the

rats best. At the start of the experiment, 10, rats each of the same size were randomly allocated to each diet. We assumed there was no competition for food as there was more than enough for the rats.

Unfortunately, in the course of the experiments, some of the rats died. The results obtained were as shown below. The data represent the net gain in weight (gms0 after two months.

A	B	C	D
1.3	2.4	0.9	3.1
1.5	1.5	1.1	3.2
2.0	2.8	1.2	2.5
2.1	1.7	0.4	4.0
2.5	3.5		3.4
3.4	3.8		3.5
	1.2		2.5
	1.4		2.8
	1.6		3.8
			4.2

Analyze the data and test for significant differences in the treatment effects.

FOLLOW-UP PROCEDURES OR POST-MORTEM ANALYSIS

When the H_o is not accepted in the ANOVA procedure, it is possible to carry out further analysis so as to obtain more information. These further analyses are called the follow-up procedures or post-mortem analysis.

The post-mortem analysis used include:

viii. Fishers' least significant difference (LSD)

ix. Duncan's new multiple range test (DMRT)

LSD

When F is significant, the LSD or ordinary t-test for the difference between two means is applied to every pair of means. The LSD itself is based on a t-test, and it is given as:

LSD = $t_{\alpha/2}$, d_{ferror} x $\left(\sqrt{\frac{MSE}{r}}\right)$ for equal number of observations per treatment, or

LSD = $t_{\alpha/2}$, d_{ferror} x $\left(\sqrt{\frac{MSE}{r_1} + \frac{MSE}{r_2}}\right)$ for unequally replicated means i.e. treatments with unequal number of observations;

Where MSE = Mean square for error (from the ANOVA table)

r = Number of observations per treatment

r_1 and r_2 = Number of observations per treatments whose means are being compared.

t = Student's t0value (i.e. t-tabulated) from the t-table $t_{\alpha/2}$ implies a two-failed test

any two means whose absolute difference exceeds the LSD value are declared significantly different.

When there are equal number of observations per treatment, a single LSD value is computed and used for the comparisons. However, when the treatment have unequal number of observations, different LSD values are computed for the comparisons

e.g. using example 2 above.

LSD = $t_{\alpha/2}$, d_{ferror} x $\left(\sqrt{\frac{MSE}{r_1} + \frac{MSE}{r_2}}\right)$

= 2.09$\left(\sqrt{\frac{15.6799}{\quad} + \frac{\quad}{\quad}}\right)$

For comparing S_1 and S_3

LSD = 2.09$\left(\sqrt{\frac{\quad}{4} + \frac{\quad}{\quad}}\right)$

= 4.4939

For comparing S_2 and S_3

LSD = 2.09$\left(\sqrt{\frac{\quad}{\quad} + \frac{\quad}{\quad}}\right)$

= 3.6031

Re-arranging the means orderly, we have;

S_3 (14.3); S_2 (10.875); S_1 (8)

Subtracting the means other, we have;

$S_3 - S_2$ = 14.3 – 1-.875 = 3.425 < 3.6031 ns

$S_3 - S_1$ = 14.3 – 8 = 6.3 > 4.4939 *

The result of the LSD procedure are then presented as follows

Treatment	Mean
S_3	14.3 a
S_2	10.875 ab
S_1	8.0 b

Means with the same letters are not significantly different at 0.05 level of significance. From this result, the best source of fertilizer is S_3. It led to high growth rate than other fertilizers.

DMRT

The DMRT is more conservative (i.e. less likely to detect real differences) than the LSD. This is because it involves several different critical differences in contrast to a single LSD value for equal number of observations per treatments.

Thus, it allows a higher rate of pairs of samples averages that are further apart when ordered by size. This conservative property of the DMRT however makes it less likely to indicate false differences.

Using example 2 above.

i. The treatment means are arranged horizontally in decreasing order and vertically in ascending order.

	S_3 14.3	S_2 10.875	S_1 8.0
S_1 8.0	6.3	2.875	-
S_2 10.875	3.425	-	
S_3 14.3	-		

ii. The number of means involved in the range being compared are also obtained and put in a table similar to that shown in (1) above

	S_3 (14.3)	S_2 (10)	S_1 (8)
S_1 (8)	3	2	-
S_2 (10)	2	-	
S_3 (14.3)	-		