INTRODUCTION

In general, statistics deals with the collection, analysis and interpretation of data. Statistics is the science of application of qualitative and quantitative techniques for making inductive inference. Statistics is concerned with the development of application of methods and techniques for collection, analysis and interpretation of numerical information to achieve defined objectives.

USE OF STATISTICS

Statistics can be useful in several situations. These include:

1. Description of situation e.g. tables and graphs to describe the yield of different crop varieties.

2. Used in decision making i.e. sampling of a handful of products from large number of random sample to determine if the quality is good or bad.

3. Accessing variability in quality e.g. Seed planter used to plant seed of different sizes

4. Degree of association between factors or variables

5. Prediction – statistics can be used to predict the yield or a crop based on the nutrient in the soil or the amount of irrigation water applied, or the yield at different planting densities

6. Statistics is the tool for carrying out scientific experiments.

ESSENTIAL STEPS IN EXPERIMENTATION

The correct choice of a statistical procedure for any experiment must be based on sound knowledge of statistics and the subject matter of the research. Thus, a good experiment can be designed by:

1. A subject matter specialist (SMS) with some training in experimental statistics

2. A statistician with some background and experience in the subject matter under experimentation

3. A joint effort and cooperation between a statistician the SMS

Problem definition

- You begin by asking questions from what you have observed over the years personally or in literature

- Establish if there is truly a problem

- After identifying the problem there is need to do a comprehensive literature review to know how far other scientists have gone on the subject matter and then identify the missing gaps in knowledge. This procedure is very important because it avoids duplication of efforts.

Definitions of Objectives

There would be one of more objectives in a research study. The objective should be very brief or concise, self explanatory and achievable.

***Objective**: To evaluate the yield potential of new soyabean varieties. You can have broad objective or general objective and (specific objectives) which always address the specific topic.*

Avoid rewriting your project title as your objective e.g. Project title: Study of the effect of fertilizer on maize varieties cassava and rewriting that as objective is wrong. The objective in this case is to determine the effect of fertilizer on yield and yield component of maize.

Choice of Treatments

Before a researcher can define experimental treatment a very good knowledge of the subject matter is needed. An experimental treatment is any process/procedure whose effect is to be measured and compared with others. The quantitative or qualitative component of a treatment is called the ***treatment levels.*** *When there are two or more types of treatments, then each treatment is referred to as* ***factor****. For example, in the study of the effects of insecticide on the control of insect pests on tomato varieties, there are two factors here, namely: the insecticides to be used and the number of tomato varieties in the study.*

Definition of Experimental Material

Any object or element of the environmental on which treatment is applied and observation made is called experimental material. The portion of unit of experimental material receiving the application of treatment is called the experimental unit or experimental plot in a field experiment.

The minimum requirements for a valid experimental design are:

Replication: *It is the application of a treatment more than once in an experiment. This is done*

1. To provide an estimate of experimental errors
2. To improve the precision of an experiment
3. To increase the scope of inference
4. To reduce or control error variance

Randomization: *Every treatment must be given equal chance of being placed within and experimental plot or a sample unit. Randomization of treatments means that the experimental error is randomly distributed, that is the residual error is not clustered. Random distribution of error is important in order to measure the level of statistical significant of effects of treatments or factors. Randomization is done to avoid bias in the allocation of treatments to plots.*

Blocking: *This is accomplished by blocking or subdividing the experimental area or experimental material to more or less homogenous groups.*

Question

What is the meaning of the following?

1. Adaptive Research

2. Basic Research

3. Applied Research

POPULATION PARAMETERS AND SAMPLE STATISTICS

Statistics is process of obtaining information about a population. Statistical information is used to make inferences about the population. Statistics deal with taking samples. Samples must be a representative of the population and the information obtained from the sample is called statistics. In order for statistics to be a representative of a population it must give a good estimate of the population parameters. Statistics provide the tool for obtaining information from samples that can apply to a whole population.

Parameters are the actual values or information obtained from a population and statistics are information obtained from samples to provide estimates of the real population parameters. There are two ways obtaining data (1) sampling/survey (2) Experimentation.

Survey: *Survey is carried out in order to describe what is happening about a large population. Survey is carried out when you go out to farmers and obtained information. One of the beauties of survey is that the problems that need research interventions can be identified from field surveys.*

Experimentation: *This involves using definite procedures of asking questions, formulating hypothesis, setting up an experiment to test the hypothesis, (usually called null hypothesis), collection of data, analysis and interpretation of the data followed by a test of hypothesis during which the hypothesis is affirmed or rejected.*

Each observation make from a sample is called a variable. Examples of variables are germination percentage, plant height, leaf area, dry matter yield and seed yield. The variables from samples may be discrete or continuous. A continuous variable has decimal places and should not be rounded up to whole numbers or integers. Examples are weight and height of the plant. Discrete variables are whole numbers or integers. Examples are days of emergence, leaves per plant and seeds per pod.

Various Statistics are used in the analysis of agricultural experiments or agricultural data. These include: Mean, mode, media, variance, standard deviation, analysis of variance (ANOVA), correlation, regression, t-test, Z-distribution, chi square and covariance analysis.

POLULATION AND SAMPLING

Population refers to a defined group that is of interest for study. It could be population of farmers in Ogun State, population of cassava growers in Ogun State or population of orange growers in Ogun State. It could be the number of women farmers in Nigerian or Number of student offering PCP501 course. A defined population or a specified population must be fairly homogenous in some respect but may be heterogeneous in other aspects. That means the *population has sub populations. If the class of student in PCP501 is a defined population, its sub-populations will be the number of male and female students. Another sub-population will be the number of students taking the course from different departments. When we measure the characteristics of an entire population, we use the term population parameters for the population data summary.*

Such parameters are population mean, population variance population standard deviation (S.D.). It is expensive time consuming and cumbersome to obtain parameters for a large population in the process of studying the population. Consequently, there is the need to take samples from the defined population for measurement and for estimating population parameters. When population parameters are estimated from samples, the estimates are called STATISTICS. Statistics therefore deals with sampling techniques, method of collecting data and analyzing the interpreting the data.

To get a good estimate of the population parameters, it must have the following characteristics:

1. It must be large enough to cover the various populations and therefore the range of variance. If otherwise a sample may not give a good estimate of the population characteristics.

2. Representative: A sample is representative when it covers the strata of the population as well as the strata variation

3. The sample must be random. Random sampling avoids bias. Random samples must be large enough and must be representative of the population.

TECHNIQUES FOR OBTAINING SCIENTIFIC DATA

1. Survey
2. Experiment

Surveys are measurement taken from nature without imposing your own conditions or treatment. Surveys provide reasons why the population behave the way it is or explain the characteristics of the data from nature. Surveys are very important agricultural data. For instance a survey can be carried out on the weed spectrum and weed control methods on farmers' field in Ogun State and the kind crops farmers grow. In an experiment, we want to impose our condition on nature and measure the effect of the treatments imposed. For example in an attempt to investigate how to reduce malnutrition in children, in Ogun State, we can decide to fortify the food of children with soymilk and see how the children will grow or respond to the treatment. We can also try to use different rates of fertilizer to increase yield.

Scientists carry out experiments in various fields. Scientific experiments share the following features:

- A review of facts, theories and proposals
- Formulation of logical hypothesis that can be subject to testing by experimental methods. A hypothesis is a proposition about a situation. The proposition may be true or not be true. An improved variety of maize will perform better than local variety in all locations. An experiment can be conducted to determine whether the hypothesis is true or not.
- Objective evaluation of the hypothesis on the basis of experimental results.

Therefore, statistics is a tool used in scientific research to determine the validity or otherwise of a scientific hypothesis.

Statistics applied to agriculture can have a variety of names such as Biostatistics, Biometrics, Field Plot Technique. Experimental Designs or Methods of Field

Experimentation. The differences are subtle depending on where emphasis is placed in the course.

PRINCIPLES OF FIELD EXPERIMENTATION

An experiment is a planned investigation that is carried out to obtain additional knowledge in order to solve identified problems and to obtain solutions to the problems. The problems can be identified from a survey, personal experience and literature search.

The identified problem must be state in unambiguous term.

- After identifying the problem, the next step is to carry out literature review – to find out how other scientists in other locations or countries had tried to solve the problem. What experimental procedure they used and the results obtained in order to ensure that your proposed experiment is properly conducted. Literature review is made easy by electronic search, library, e-mail correspondence etc.

- Clearly state the objective of the work. The objective must be straight forward and simple. It must be specified to ensure that the study is properly focused and the right results are obtained.

- Setting up of hypothesis: The hypothesis is state in the negative. This null hypothesis (Ho) states for instance that there are no differences in the yield of the varieties to be evaluated. The alternate hypothesis (Ho), will be accepted if the experiment shows otherwise.

- Designing of experiment: To be able to answer the problem, the scientist will

- Conduct the experiment

- Collect data

- Statistically analyse the data

- Interpret the data and Report the results obtained

FIELD EXPERIMENTATION PRACTICES

- Field preparation
- Choice of treatment and factors
- Choice of design and number of replications
- Plot labeling
- Treatment randomization and layout of the experiment
- Planting and application of treatments in the field
- Handling of experimental material

- Experimental unit and sampling unit
- Size of guard or border row
- Data collection, handling and processing

Filed preparation must be timely including ploughing, harrowing, leveling and removing the entire stump.

Choice of design depends on the location, homogeneity of the site. It depend on the number of factors to be investigated.

Treatment randomization is very important to avoid bias in allocation of treatment to experimental plots. Randomization is important to correct and minimize residual error. The smaller the experimental error, the better is the precision of the experiment.

Field layout: In the field lay out the site, location, orientation relation to N.S.E.W. or road, the number of plot, replicate, the treatment number must be clearly shown. It must be typed and printed and given to all participants in the experiment.

Planting and application of treatments in the field has to be done at the right time. The treatment number must be put on label and place on the plot.

Handling of experimental material: Experimental materials must be carefully handled to avoid spoilage, leakage, overdose or under dose during measurement, transportation and application on the field. Also, contamination of contaminable materials must be avoided.

Experimental unit and sampling unit: The experimental unit is usually called the Gross plot size. It is the smallest unit in the experiment. Each experimental unit receives a treatment. The sampling unit is a portion of the experimental unit. It defines the portion from where sample is taken for measurement.

Size of guard/border row: The size of an experimental unit or plot must be large enough to avoid border effect. That is there must be guards rows. The advantages of border row include:

1. It gives protection or shield or break when applying different fertilizer rates or pesticides from one plot to the other plot.

2. It helps to reduce border effect because border plants grow better than other plants within the plot.

DATA COLLECTION

- Collect the data in a log book

- Summarize data the same day that you collect the data

- Avoid using loose paper to collect data

- It must be readable by other persons

- Where sample has to be weighed or dried, it should be labeled and properly packed in a paper bag.

- Counting and weighing procedure must be adequate

- Summarized data must carry sampling date, name of variable, unit of measurement and location of the experiment

- The summarized data must be neatly presented for statistical analysis

CONTENTS OF A RESEARCH

Title

Problem definition

Objectives

Material and Methods

Plot layout diagram

Work plan

Data sheet and Data collection

Gross and net plots

Data analysis

Presentation of experimental results

Log frame

The objective of a field experimental is to find scientific means of enhancing the quality and quantity of physical resources for crop production e.g. solar radiation, water, lands, fertility.

Various practices and factors affect or determine crop performance and yield in the field. Such practices and factors include: tillage practices, fertilizer management, water management, pests and diseases management. Field experiments are carried out to determine the best practices that will increase the efficiency of crop production.

A title is formulated from the focus of the subject matter i.e. How can the efficiency of fertilizer be increased in order to get more better crop growth and yield? Title has to be brief, concise and clear. The title should reflect the objectives and the materials or factors being investigated.

Introduction*: The introduction provides information on the nature of the problem being addressed, the purpose, scope and justification of the experiment. There is no standard format in writing the introduction. The problem being addressed in the experiment must be clearly identified. How the problem was found out should be stated. What and where attempts have* *been made to solve such problem, if any and why it is still important to carry out the experiment. The scope of the experiment is the extent to which the identified problems for which the experiment being proposed will be tackled. It is important state what had been done or achieved by similar experiments in the past and what remains to be done. The introduction should also state why this study is important or what will be the importance of the solution to the problem that is being addressed.*

Objectives*: The objective or objectives of the experiment are stated at the end of the introduction. It is still a part of introduction. It cannot be omitted in good report writing. The objective spells out briefly and accurately the specific focus of the problem that the experiment wants to solve. In order words the objective states the question the experiment wants to answer.*

Literature Review*: This is the process of searching for information on previous studies on the topic and materials under investigation. The most important source of research information is Journal Publication, followed by books and then the internet. In reporting an experiment it is always vital to provide a review of literature to ensure that the investigator or researcher is familiar with progress and most recent developments in the chosen field of research. Literature review also prevents the duplication of research efforts. It also helps to improve the choice of materials and experimental methods.*

Material and Methods *The area, location and duration of the experiment must be stated. It is very important to describe the location, the climatic conditions of the site and the soil type. The type of land preparation, the plot size, description of treatments and factors used as well as the experimental design and number of replications used should be stated. The duration of the experiment must be stated.*

Material: Information must be provided on the general cultural practices, such as land preparation, fertilizer application and control of weeds, insects and other pests that my interfere with the experiment. The rate per hectare of blanket applications of fertilizer, insecticides, herbicides and others used should be stated. The name of crop varieties used and the source of the seeds or planting materials should be stated.

Experimental design

Randomization and Field Orientation: State the specific design you want to used including number of factors, treatments and the number of replicates. It is important to state the dimension of the net plot and the gross plot size.

Treatment: State the number of treatments and how the treatments were applied. The treatments must be described e.g. crop varieties or fertilizer levels or plant populations or different concentrations of insecticides or chemical used.

Land preparation: Mention how the land was prepared. Hand clearing, bush burning or ploughing and harrowing or with the use of herbicide.

Fertilizer management: You have to state clearly the kind, the time, the rate and how it will be applied.

Weed management: You must describe fully the method of weed control. If herbicides are use, the kind, rate and time and how the herbicide is to be applied, the number of time and the stage of cultivation must be stated.

Insect and Disease Control: State time, rate, kind and how to apply chemical to control pest and disease. It is important to include target insect to be controlled.

Data Collection: Data to be collected must be stated and the intervals or growth stages when the data will be collected should also be stated before the experiment starts. In some *experiments, unexpected situations may warrant taking additional data than what was contained in the project proposal.*

Harvesting: This must be done at the approximate time. The method of harvesting, sampling procedure, sample size, method of sampling should be stated where necessary. The entire plant stands in a plot from GROSS PLOT size. The proportion of the gross plot size to be sampled is referred to as NET PLOT. The discard or border rows surround the plot to prevent injuries or other form of interferences with the gross plot size. Harvest is done anytime after physiological maturity.

POST HARVEST HANDLING: Indicates whether the samples will be weighed fresh or dry. If dry state whether it is sun dried or it is going to be oven dried. If it is to be oven dried, at what temperature?

***DATA ANALYSIS**: State the statistical methods to be used in analyzing the data e.g. analysis of variance, mean separation, correlation or regression.*

SOURCES OF VARIATION IN FIELD EXPERIMENT

This is can be called variation or variability

- *Variability in biological material: Agricultural experiments. Involve biological materials. Biological materials are highly variable in size, weight and response to the same environmental resources e.g. a given seed lot, a variety of cowpea or maize. A seed lot from the same variety can't have the same weight for every seed. The seed size, seed weight, germination date, germination rate are different among seeds within the same seed lot.*

- *The soils on which plants grow are also not homogenous in texture, nutrients content and organic matter etc. All these will increase variability of the growth of the plant and therefore the data to be collected.*
- *Lack of uniformity in treatment application: Some treatments can't be completely uniform e.g. you can't have the same size of yam tuber.*
- *Uncontrollable factors: There are uncontrollable or unforeseen problems that arise in field experiment which can increase variability in the data or distort the result from the experiment e.g. stealing, attack by rodents, pests, diseases, nematodes infestation.*

These above sources of variation introduce what is called experimental error or residual effect in field experiments. Residual effect is due to the normal variation in biological materials and other causes outlined above.

In order to minimize residual error there is the need to increase the precision of an experiment.

1. Problem of soil heterogeneity (slope of the land) you must look at the vegetation of the land on which the experiment is going to be carried out before it is ploughed. After ploughing and harrowing, look at the soil texture in terms of the proportion of sand, silt and clay and you may carry out chemical analysis of the plots. Through the understanding of the vegetation or soil heterogeneity, the experimental plot can be stratified, such that each replicate of the experiment can be placed on different but relatively homogenous soils.

2. Uniformity trial is a trial or experiment that is carried out or run before the real experiment. The purpose is to even out the soil fertility by planting a crop that can take up all the nutrients in the soil prior to the implementation of the real experiment.

Uniformity trial is usually carried out prior to setting up a fertilizer trial or experiment. Uniformity trial can be statistically analysed as if real treatments have been imposed.

3. Choice of appropriate design. Different designs can be used to carry out different experiments. The choice of experimental design depends on the heterogeneity or otherwise of the soil. Some designs can be used to correct the defects in the field. Such defects like soil heterogeneity. The field environment is not so homogeneous. Unlike the green house. Your design must be able to capture the variability on the field.

4. Randomization: Can be defined as giving all treatments equal chance of falling into any plot in the field. There are different methods of randomization e.g. testing different kinds of herbicides on maize plot. You can use card, disc and table of random numbers etc to carry out randomization. You can randomize (n-1) which is called the degree of freedom. The extent to which you can randomize is 0-1. A disc which four side is called tetrahedron.

5. Ensuring uniformity of experimental materials e.g. Yam cuttings, cassava cuttings.

6. Collection of additional data: This is data that was not planned to be collected. If or instance some plots were attacked by rodent or insect, you have to do is to score the damage of the rodent or insect attack e.g. the scores can be attack, low attach, severe attack, very severe attack with scores of 1,2,3,4,5 respectively. In co-variance analysis, you use the additional date (score) to adjust or correct your actual data. The co-variate (addition data) can be used to correct your actual data (yield) with covariance analysis.

7. Treatment Levels: In selecting treatment levels, ensure the treatment levels are as wide as possible.

8. Plot Size: Sizes or experimental unit or plot must be large enough to overcome heterogeneity in the field and to accommodate destructive sampling.

9. Replication: In an experiment it's good to have 1-8 replicates.

Merits of Replication

1. Helps to remove the problem of soil heterogeneity by calculating and removing what is called block effect from the sources of variation

2. It reduces the value of the error. The smaller the residual error, the more it's easy to recognize the significant differences and vice-versa.

Methods of Reducing Experimental Error

1. Choice of appropriate design
2. Randomization
3. Replication
4. Uniformity trial
5. Collection of additional data
6. Co-variance analysis
7. Careful selection of treatments
8. Selection of correct experimental unit.

DIFFERENCE BETWEEN ACCURACY AND PRECISION

Experiments are conducted to obtain specific information as an addition to knowledge e.g. how will new varieties of cowpea respond to nitrogen fertilizer. These questions require setting up experiment to get specific answer to such question.

An experiment that was badly planned or poorly implemented will not give the right answers. Badly implemented experiment lacks the precision required to detect treatment effect e.g. whether, 90kg of Nitrogen applied to maize is not as good as 120kgN applied to maize. Inaccuracy and lack of precision are problems in poorly conducted experiment.

PROBLEM OF PRECISION (ACCURACY/INACCURACY

Accuracy refers to the ability of a scientist/student to carry out or measure precisely what is intended to be measured.

To collect data in the field you need to prepare a data sheet like the one below:

Name of experiment: Cowpea/maize intercropping

Observation: Cowpea dry matter yield

Date: Nov. 24, 2005

Treatment	*Rep 1*	*Rep 2*	*Rep 3*	*Rep 4*	*Xn*
0KgN					
4.5KgN					
9.0KgN					
120KgN					

You must keep accurate records. Accuracy is about how you carry out your weighing and measurements without any systematic error. When you weigh, there must be no systematic error *in the weight (make sure the balance is not faulty). Another source of systematic error occurs when you approximate your figures.*

Accuracy also means that when you are planting, the planting and treatment must be carried out accurately. Such inaccuracies will affect the result of your data and the results from the experiment.

Inaccuracies introduce large variability in experimental data. Variability that was not due to treatment or factor under study. Such large and undesirable variation will increase experimental/residual error.

Inaccuracy will increase experimental error and decrease precision. Precision in experimentation means getting the experimental procedure right such as choice of right design make sure that there is correct randomization, replication etc . to minimize experimental error.

It is important to differentiate between accuracy and precision.

Accuracy: is the ability of a student to carry out or measure precisely what is intended while precision is the ability of a student to get the experimental procedure right, such as choice of right design.

EXPERIMENTAL DESIGNS

- Completely Randomization Design (CRD)
- Randomized Complete Block Design (RCBD)
- Latin square
- Split plot design
- Split-split plot design

- Split block design

For each of the above designs it is very important to be:

- Randomize the treatments or factors within each design
- Label the plots in the field
- Know the advantages and disadvantages of each design
- Able to collect the data correctly on the field
- Know the sources of variation
- Assign correct degrees of freedom for sources of variation
- Able to calculate Sum of Squares for each variation
- Calculate Mean Squares
- Compute error or Error Mean Square
- Calculate F-Ratio
- Test for Significance
- Separate Means

COMPLETELY RANDOMIZATION DESIGN (CRD)

It is the simplest design. It is good for laboratory, green house and pot experiments. It is therefore suitable or efficient where conditions are homogenous. In the design, as many treatment can be used because of its simplicity and flexibility.

Disadvantages: It doesn't give a very good measure of experimental error i.e. it has low error precision where experimental material or environment is heterogeneous.

Randomization in CRD

Rhizobium strains

USDA 1	*1*	*6*	*11*	*16*
USDA 33	*2*	*7*	*12*	*17*
USDA 44	*3*	*8*	*13*	*18*
USDA 75	*4*	*9*	*14*	*19*
Control strain	*5*	*10*	*15*	*20*

The randomization of treatments in a 4 x 4 Latin square is as shown:

Rep I	*Rep II*	*Rep III*	*Rep IV*
D	*C*	*B*	*A*
A	*B*	*D*	*C*
C	*D*	*A*	*B*
B	*A*	*C*	*D*

The heterogeneity that Latin square can control in two directions could be in the environment (soil) or planting material or both soil and planting material.

e.g. (1) Soil that slopes in two directions

(2) Slope

LATIN SQUARE DESIGN

Advantages

1. Takes care of heterogeneity in 2 directions
2. Has more precision than CRD and RCBD

The Disadvantages

1. The number of rows must be equal to the number of blocks (columss and equal to number of treatments).
2. Therefore it becomes cumbersome to analyse when the number of treatments exceed five or six.

The Design

Because of the number of rows and columns must be equal i.e. square the design could be a 3 x 3 or 4 x 4 or 5 x 5 0r 6 x 6 Latin square in one direction and water table in another direction.

3. Only slope in one direction but the other heterogeneity in the planting material e.g. cassava cutting or yam tuber cut into different maturity stages and different stages put into different blocks.

SPLIT PLOT DESIGN

This is strictly spreading an arrangement of treatments rather than a design. The slip plot arrangement is in RCBD. The number of replication can be as many as desirable. Usually between 3 or 4 or 5.

Advantages

1. The split plot design is very useful for a two-factor trial or experiment particularly where special consideration is given on the ease or convenience of arranging the factors and treatments in the field. In such situations RCBD will not be a convenient design.

2. Because of its flexibility the randomization and application of treatments in the field is much earlier and more convenient that for standard RCBD.

The Main Disadvantages are:

1. It is commonly used for two factors only. Although an expert in biometrics can use it for trials involving 3 or four factors

2. The precision for testing the significance of treatment differences as main plot and sub plot levels are different. The precision being higher for subplot treatments than for main plot treatments.

3. The calculation of missing plot values can be more cumbersome.

Assuming you want to evaluate the effectiveness of three contact insecticides on four varieties of cowpea in the control of flower and pod eating pests.

If you have a 3 x 4 factorial arrangement of treatments, how do you randomize this is a split plot design.

The factorial combinations could be 2 x 3, 2 x 4, 3 x 4, 3 x 5 etc. The number of replicates could be 3 or 4.

The decision about what factor to put in the main plot or in subplot is determined by:

(1) Ease of assignment of treatments e.g. performance of maize varieties on two different land preparation methods will require putting land preparation method in main plot because it will be easier to do so.

(2) Put the more important factor in subplot with higher precision so that treatment differences can be easily detected.

Before any experiment we must state the null hypothesis which will apply to every observation or variable measured in the experiment (Plant height, leaf area, dry matter yield, grain yield, score of pathogen infection etc).

$$\frac{208^2 + 224^2 + 272^2 + 224^2}{4} - CF = 576$$

ANOVA Table

					Require F	
SV	D.f	SS	MS	Obs.F	5%	10%
Total	15	854				
Block	3	576	192.0	24.69**	3.86	6.99
Treat	3	208	69.3	8.91**		
Error	9	70	7.78			

Compare the precision, error value (FMS) in CRD (53.8) with RCBD 7.78 and the effect on F-ratio.

Also the residual is obtained by sweeping Treatment mean and then Block means.

It is wrong and unacceptable to use a design that you did not use to implement a trial to analyse the data.

Mean Square for Error or Error Mean Square

MSE represents variability among capital units that remains after removal of other sources of variation.

This Residual effect or MSE can be seen by removal or sweeping technique if block effect and then removal of treatment effect.

Block 1 effect is block means – GM: $X_b - X_g$

52 58 -b: which should be subtracted from each variety in BL 1

I

47 – (-6) 53

50 – (-6) 56

57 – (-6) 63

54 – (-6) 60

Block II effect 56 – 58 = -2

Block III effect 68 – 58 = +10

Block IV effect 56 – 58 = -2

Varieties with Block effect removed

	I	II	III	IV	Total	Mean
V_1	53	54	53	53	212	53
V_2	56	56	57	59	218	57
V_3	63	55	59	59	236	59
V_4	60	67	64	61	252	63
	232	**232**	**232**	**232**		
Mean	**58**	**58**	**58**	**58**		

Removal/Sweeping Away of Treatment effects

V_1	53	58	-5
V_2	57	58	-1
V_3	59	58	+1
V_4	63	58	+5

Removal of Treatment effects from the above table to get the next table corrected now for block or treatment effects

	I	II	III	IV		X
V_1	58	59	57	58	232	58
V_2	57	57	58	60	232	58
V_3	62	54	59	58	232	58
V_4	55	62	59	56	232	58
X	**58**	**58**	**58**	**58**	**58**	

Mean square for error is the

Square of each residual

4(4) – (4 – 1) – (4 – 1)

Total (Treat) (Block)

$(58 – 58)^2 + 59 – 58^2$ *………... ‘* $(56 – 58)^2$

1(4) (4) - 1[-4 -1 – (4-1)]

= 70/9

= ***7.78***

ANOVA in Latin Square 4 x 4 LS

Rep I	*Rep II*	*Rep III*	*Rep IV*	*Total X*
D54	*C65*	*B67*	*A51*	*237*
A47	*B54*	*D74*	*C57*	*232*
C57	*D53*	*A62*	*B57*	*229*
B50	*A52*	*C69*	*D59*	*230*
Total 208	***224***	***272***	***224***	***928***

ANOVA

S.V.	*D.F*	*SS*	*EMS*	*Feal*	*F Tab*	
Total	*15*	*854*			*0.05*	*0.01*
Column	*3*					
Row	*3*					
Treatment	*3*	*208*				
Error	*6*					

ANALYSIS OF FACTORIAL EXPERIMENT

What is very important in factorial experiments or even single factor experiment is that:

(1) The total for each factor and the totals for the interactions must be clearly identified

(2) The number of varieties that add up to give the totals for each factor or interaction should be used as the division for the square of the variable before the C.T. is subtracted.

(3) Otherwise the sum of squares will be wrong (larger or smaller in value or negative)

(4) The SS is **never** negative for any source of variation because it is the square of deviations from the mean or sum of square.

Assuming I have the following

2 x 3 factorial mean A at 2 levels, B at 3

3 x 2 factorial mean A at 3 levels, B at 2

3 x 2 factorial mean A at 3 levels, B at 3

The null hypothesis for this experiment is that none of the four varieties is in anyway better or superior to the other

Ho: Xv1 = Xv2 = Xv3 = Xv4

Ho: Tv = V2 = 0. Treatment positive if is zero

Ho: Ti = Vi / 0

Ho: Xv1 = Xv2 = Xv3 = Xv4

The linear Model for CRD

The values Xy = have a mean, a treatment effect and a residual variation.

Xy = Xy + Ti + Ei

Where Xy is any of the values in the sixteen experimental plots.

The Linear Model for CRD

Xy = Xy + Ti + Bi + cy

Xy = is the mean – or Grand mean

Ti is Treatment effect

Bj is Block effect

Eij is error term or residual effect

Linear Model for Latin Square

Xijk = Xijk + Ti + Rj + Ck + eijk

Take any value 67 = 58 + 5 + 1+ 2 + 3

Ti = Treatment effect

Rj = Block or Column effect

CK = Row effect

Eijk = is error term

Plant height (cw) or maize varieties to 60 DAP in four replicated + CRD

	I	II	III	IV	Total	X
V1	47	52	62	51	212	53
V2	50	54	67	57	228	57
V3	57	53	69	57	236	59
V4	54	65	74	59	252	63
					928 (Grand Total)	58 (Grand mean)

(X – X)2 = x/t2 - (x)2

n

(x – 1) n – 1

Sources of variation	D.f	SS	MS	F-ratio		F-Tab
Total	15	854			%	%
Treatment	3	208	69.3	1.29	3.49	5.95

Error	12	646	53.8			

SST = 472 + 522 ------------------------592 - cf

CF = 9282 = 53824

16

SST = 54678 - 53824 = 854

SSt = 2122 + …….. 2522 - CF

4

= 54032 - 53824 = 208

SS is always positive if – ve, it means cf is not correct or X2 is not correct

SSe = 854 - 208 = 646

Residuals = Sweep the means from each value

Square the residuals and subtract Cf = SSe

Interpretation of data

Data is taken on growth and yield so that growth data can be used to explain yield data.

Does the improved variety have more vigorous growth (plant height) or more leaf no, or layer leaf area or are the leaves more upright to explain why the yield is significantly better than that of other varieties.

Plant height of maize at 60 DAP in your replicated in RCBD

	I	II	III	IV	Total	X
V1	47	52	62	51	212	53
V2	50	54	67	57	228	57
V3	57	53	69	57	236	59

V4	*54*	*65*	*74*	*59*	*252*	*63*
	208	*224*	*272*	*224*	*928*	*58 = XGM*

$$SSB = \frac{Bt2}{4} - CF$$

3 x 4 factorial mean A at 3 levels, B at 4

4 x 3 factorial mean A at 4 levels, B at 3

2 x 2 x 4 factorial mean that A, B & C are at 2, 2 & 4 levels respectively.

For A at 3 level and B @ 2 levels, the treatments for the experimental units are generated as follows:

A1 B1 = A1 B1

B2 = A1 B2

A2 B2 = A2 B1

B2 = A2 B2

A3 B1 = A3 B1

B2 = A3 B2

Note that simple effects can be algebraically calculated. This is not part of ANOVA.

B Effect A1 B1 + A2 B1 + A3 B1 - A1 B2 - A2 B2 - A3 B2

A2 effects A2 B1 + A2 B1 - A1 B1 - A2 B2

A3 effects A3 B1 + A3 B2 - A2 B1 - A2 B2

2 x 3 factorial in split plot with 3 replicates

18 plots

ANOVA Table

S.V.	*D.F.*	*SS*	*EMS*	*Fcal*	*FTab*	
					0.05	*0.01*
Total	*(17)*					
Fact A	*1*					
Block	*2*					
Ea	*2*					
Fact B	*2*					
A x B	*2*					
Error b	*8*					

Grain yield of varieties of maize with and without manile tons ha-1 and fertilizer

		I	*II*	*III*
A1 B1		*1.4*	*1.1*	*1.1*
A1 B2		*1.3*	*1.4*	*1.2*
A1 B3		*1.5*	*1.5*	*1.4*
A2 B1	*2.1*	*2.0*	*1.8*	
A2 B2	*2.6*	*2.3*	*1.9*	
A3 B3	*2.8*	*2.6*	*1.9*	

Note that when the treatment are arranged by the side the values are for collected

Calculate the totals and sum of square the Anova.

2 x 3 factorial in RCBD with 3 Replicated

No of plots 18

ANOVA Table

S.V	*D.F*	*SS*	*MS*
Total	*17*		
Blocks	*2*		
Treatments		*(5)*	
A	*1*		
B	*2*		
A x B	*2*		
Error	*10*		

Calculate the SS.