COURSE GUIDE

SLM 312
REPORT WRITING IN SOIL SCIENCE

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INTRODUCTION

You are highly welcome to *Report Writing in Soil Science (SLM 312).* This is a two (2) credit unit course designed for students' agricultural sciences. This course has six (6) study units and presents the fundamental concepts of report writing in soil science. The lectures cover areas such as; experimental designs, field experimentation, the use of statistics and graphics, technical report writing, theses and dissertation, journals and their formats.

This course material is equipped with worked examples and tutor-marked assignments. Also, it is designed to give you a brief description of the contents of the course, the work to be done and the materials that you need. There is also a list of relevant textbooks that could be consulted for further reading/learning.

Assignments and exercises were meant to acquaint students with examinations and make them pass with excellent grades. If you take your assignments and exercises serious, I am sure you will all excel without casualties.

WHAT YOU WILL LEARN IN THIS COURSE

In this course, you have the course units and a course guide. The course guide will inform you briefly what the course is all about. It is a general overview of the course materials you will be using and how to use those materials. It also helps you to allocate the appropriate time to each unit so that you can successfully complete the course within the stipulated time frame.

The course guide also helps you to know how to go about your Tutor-marked-Assignment which will form part of your overall assessment at the end of the course. Also, there will be tutorial classes that are related to this course, where you can interact with your facilitators and other students. Please you are encouraged to attend these tutorial classes.

This course will expose you to report writing, field experimentation, the use of statistics and graphics, technical report writing, theses and dissertations, journals and their formats, the knowledge will be helpful to you during your project and even after graduation.

COURSE AIMS

This course aims to enable you to know and understand how to; write a scientific report, understand the use of statistics and graphics, write a technical report, theses and dissertation, journals and their format.

COURSE OBJECTIVES

The objective of this course is to enlighten you about the concepts of report writing in soil science. To achieve the aims mentioned above, the course has overall objectives. In addition, each unit has also specific objectives. The unit objectives are given at the beginning of a unit; you should read them before you start working through the unit. You may refer to them in the course of your study of the unit, so as to check on your performance and understanding. Go through the unit objective after completing a unit, so as to be sure that you have done what is required of you by the unit. At the end of the course, you should be able to;

- discuss the various types of experimental designs
- highlight the procedures for data collection
- highlight the contents of a research
- identify the sources of variation in experimental design
- define and discuss the usefulness of statistics and graphics
- highlight and discuss the reporting structure in a technical report
- highlight the standard sequence of a theses/dissertation
- discuss the features of a journal

WORKING THROUGH THE COURSE

To successfully complete this course, you are required to read and understand each study unit, read the textbooks and other materials provided by the National Open University. Reading the reference materials can also be of great assistance.
There will be a final examination at the end of the course. The course guide provides you with all the components of the course, how to go about studying and how you should allocate your time to each unit so as to finish on time and successfully.

STUDY UNIT

The course is divided into six (7) units. The following are the study units contained in this course:

Unit 1: The first unit defines what experimental design is, the various types of experimental designs; their advantages and disadvantages, and analysis of factorial experiment

Unit 2: Defines field experimentation and its practices, methods of data collection, contents of a research, sources of variation in field experimentation, merits of replication, methods of reducing experimental error, difference between accuracy and precision, problem of precision.

Unit 3: Defines statistics and graphics, the usefulness of statistics and graphics, graph parts, types of graphs.
Unit 4: Defines Technical Report, gives a structure of a technical report
Unit 5: Defines theses and dissertations, gives an organizational sequence of a theses/dissertation.
Unit 6: Defines Journal and its format, highlights features of a journal, presents a sample of a scientific journal.

SET OF MATERIALS

Each unit has a list of recommended materials. Go through the recommended textbooks and materials for necessary assistance while going through the unit and before attempting the exercises. Where you think you cannot find the necessary references that have been quoted in any of the units; just go online and type in the name of the author on Google, and from there you can find all relevant materials needed.

ASSESSMENT

You will be assessed in two ways in this course – the tutor-marked assignments and a written examination. You are expected to do the assignments and submit them to your tutorial facilitator for formal assessment in accordance with the stated deadlines. Your tutor marked assignment will account for 30% of the total course.

TUTOR MARKED ASSIGNMENT

There are tutor-marked assignments at the end of every unit which you are expected to do. You are expected to go through the study units very carefully so that you can attempt the self-assessment exercises. You will be assessed on the different aspects of the course but only three of them will be selected for continuous assessment. Send the completed assignment (when due) together with the tutor-marked assignment form to your tutorial facilitator. Make sure you send in your assignment before the stated deadline.

FINAL EXAMINATION AND GRADING

The modalities for the final examination for SLM 312 will be determined by NOUN. The pattern of the questions will not be too different from those you have responded to in the tutor-marked exercises. However, as the university has commenced online examinations, you may have to adjust to whatever format is made available to you at any point in time. Nonetheless, you can be assured of the content validity of the examinations. You will only be examined strictly on the content of the course, no matter the form the examination takes. It is thus advisable that you revise the different kinds of sections of the course properly before the examination date.

HOW TO GET THE BEST FROM THE COURSE

The study units in this course have been written in such a way that you can easily go through them without the lecturer being physically around and this is what happens in distance learning. Easy study unit is for one week. The study units will introduce you to the topic for that week; give you the objective for the unit and what you are expected to be able to do at the end of the unit, follow these religiously and do the exercises that follow.

TUTORS AND TUTORIALS

There are 6 tutorial hours for this course. The dates, time and location of these tutorials will be communicated to you as well as the name and phone number of your tutorial facilitator. You will also be notified of your tutorial group. As you relate with your tutorial facilitator, he/she will mark and correct your assignment and also keep a close watch on your performance in the tutor-marked assignments and attendance at tutorials. Feel free to contact your tutorial facilitator by phone or email if you have any problem with the contents of any of the study units.

UNIT 1 EXPERIMENTAL DESIGNS

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content (Experimental Designs)
    3.1 Completely Randomisation Design (CRD)
    3.2 Latin Square Design
    3.3 Split Plot Design
    3.4 Analysis of Factorial Experiment
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

Experimental design as a subset of scientific investigation is a popular and widely used research approach. The essence of experimental design and perhaps the most important reason researchers choose to design and conduct experiments is the precision with which one can analyze the relationship between and among variables and to make that analysis as objective as possible.

2.0 OBJECTIVES

By the end of this unit, you will be able to;

- define experimental design
- list the types of experimental designs we have
- advantages and disadvantages of the various types of experimental designs

3.0 MAIN CONTENT

Experimental Design

Experimental design is the process of carrying out research in an objective and controlled fashion so that precision is maximized and specific conclusions can be drawn regarding a hypothesis statement. Generally, the purpose is to establish the effect that a factor or independent variable has on a dependent variable.

To look at it from another perspective, experimental design minimizes ambiguity and attempts to eliminate confusion.

- 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:

- 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

3.1 Completely Randomisation 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 treatments 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.

Randomisation 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

3.2 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 (colums 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 or 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.

3.3 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 in 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 mainplot 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).

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

$= 576$

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: Xb - Xg

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
V1	53	54	53	53	212	53
V2	56	56	57	59	218	57
V3	63	55	59	59	236	59
V4	60	67	64	61	252	63
	232	232	232	232		
Mean	58	58	58	58		

Removal/Sweeping Away of Treatment effects

V1	53	58	-5
V2	57	58	-1
V3	59	58	+1
V4	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
V1	58	59	57	58	232	58
V2	57	57	58	60	232	58
V3	62	54	59	58	232	58
V4	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					

3.4 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	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 = $\frac{928^2}{16}$ = 53824

SST = 54678 - 53824 = 854

SSt = $\frac{2122 + …….. 2522}{4}$ - CF

= 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?

4.0 CONCLUSION

Experimental design is the process of carrying out research in an objective and controlled fashion so that precision is maximized and specific conclusions can be drawn regarding a hypothesis statement. Experimental design methods includes;

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

5.0 SUMMARY

In this unit we have learnt;

- What experimental design is
- Various methods of experimental design
- Advantages and disadvantages of experimental design methods

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the followings;
- Experimental design
- Randomized Complete Block Design (RCBD)
- Split-Split Plot design
- Split block design

2. 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 =

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

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

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.

7.0 REFERENCE/FURTHER READING

Box, G.E.P.; W.G. Hunter; J.S. Hunter Statistics for Experimenters: An Introduction to Design, Data Analysis and Model Building. John Wiley & Sons, 1978.

McBean, E.A.; F.A. Rovers. Statistical Procedures for Analysis of Environmental Monitoring Data & Risk Assessment. Prentice Hall, 1998.

UNIT 2 FIELD EXPERIMENTATION

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
  3.1 Field Experimentation Practices
  3.2 Data Collection
  3.4 Contents of a Research
  3.5 Sources of Variation in Field Experimentation
  3.6 Difference Between Accuracy and Precision
  3.7 Problem of Precision (Accuracy/Inaccuracy)
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References

1.0 INTRODUCTION

In soil science, the research have to go to the field to collect data for analysis that will eventually be used to support his hypothesis. The field could be an open land or a laboratory where specific chemical analysis is being carried out. It could even mean administration of questionnaire to households in some specific villages.

2.0 OBJECTIVES

By the end of this unit, you should be able to;

- discuss the principles of field experimentation
- discuss the field experimentation practices
- highlights the procedure for data collection
- highlight the contents of a research
- sources of variation in experimental design
- highlights the methods of reducing experimental error
- differences between precision and accuracy

3.0 MAIN CONTENT

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

3.1 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.

3.3 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

3.4 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.

3.5 Sources of Variation in Field Experimentation

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.

3.6 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.

3.7 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, 2021

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.

4.0 CONCLUSION

Field experimentation 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.

5.0 SUMMARY

In this unit we have learnt;

- What field experimentation is all about
- Field experimentation practices
- Data collection
- Contents of a research
- Sources of variation in field experimentation
- Merits of replication
- Methods of reducing experimental error
- Differences between accuracy and precision
- Problems of precision

6.0 TUTOR-MARKED ASSIGNMENT

1. Highlights the processes used to increase precision of an experiment
2. Highlights the methods of reducing experimental error
3. Differentiate between accuracy and precision
4. Discuss the field experimentation practices

7.0 REFERENCES/FURTHER READING

Donnelly R.A. (2004). The complete idiot's guide to statistics (Vol. the complete Idiot's guide.) Indianapolis, IN: Alpha

Gomez, K.A., & Gomez A.A. (1984). Statistical Procedures for agricultural research (2nd Ed) New York: Wiley.

Kaps, M., Lamberson, W.R., & Lamberson, W. (2004). Biostatistics for animal science, Wallingford: CABI Publishing

McDonald, J.H. 2014. Handbook of Biological Statistics (3rd Ed). Sparky House Publishing, Baltimore, Maryland

(http://www.biostathandbook.com/index.html)

Weiss N.A. 1999. Elementary Statistics, fourth edition. Reading, Massachusetts: Addison-Wesley Publishing Company

UNIT 3 THE USE OF STATISTICS AND GRAPHICS

CONTENTS

1.0 Introduction
2.0 Objective
3.0 Main Content
 3.1 Graphics
  3.3.1 Scattergram
  3.3.2 Line Graph
  3.3.3 Bar Graph
  3.3.4 Histogram
  3.3.5 Pie Chart
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 Reference/Further Reading

1.0 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.

2.0 OBJECTIVE

By the end of this unit, you should be able to;

- define statistics
- discuss the usefulness of statistics and graphics
- highlight the different parts of a graph
- discuss the various types of graphs

3.0 MAIN CONTENT

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 samples 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.

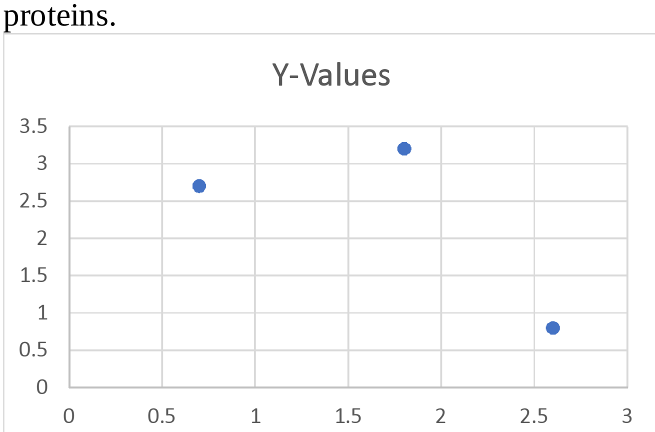
3.1 Graphics

Graphics are a common method to visually illustrate relationships in the data. The purpose of a graph is to present data that are too numerous or complicated to be described adequately in the text and in less space. A basic requirement for a graph is that is clear and readable. This is determined not only by the font size and symbols but by the type of graph itself. It is important to provide a clear and descriptive legend for each graphs. Graphs may have several parts, depending on their format: (1) a figure number (2) a caption (not a title) (3) a headnote (4) a data field (5) axes and scales (6) symbols (7) legends and (8) a credit or source line. Graphs should always have at minimum a caption, axes and scales, symbols and data field.

It is crucial to choose the correct graph type based on the kind of data to be presented. If the independent and dependent variables are numeric, use line diagrams or scattergrams; if only the depending variable is numeric, use bar graphs; for proportions, use bar graphs or pie charts.

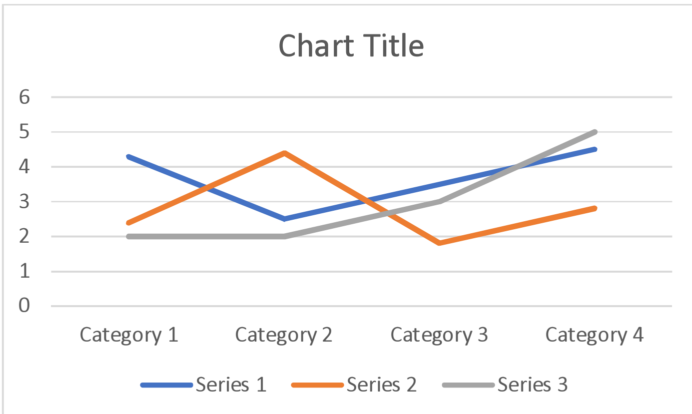
3.3.1 Scattergram

A scattergram is used to show the relationship between two variables and whether their values change in a consistent way, such as analyzing the relationship between the concentration levels of two different proteins.



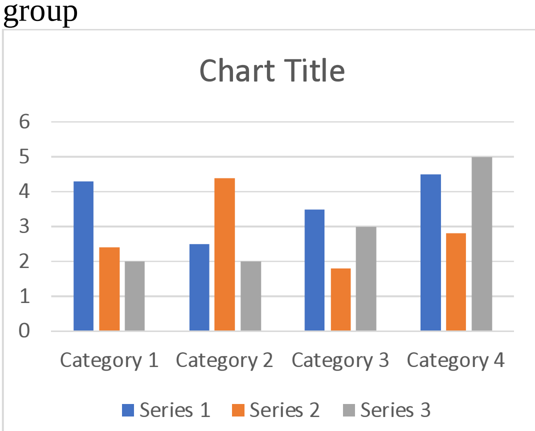
3.3.2 Line Graph

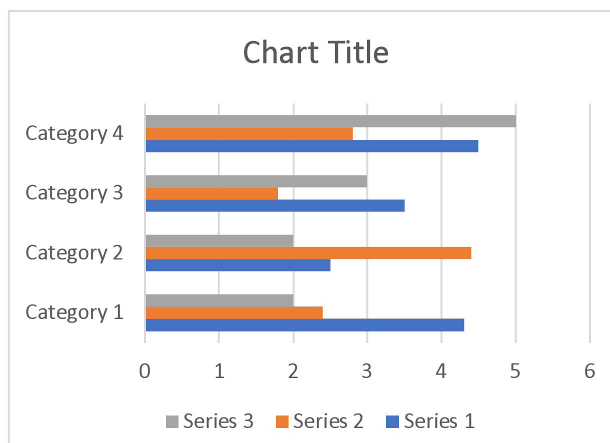
A line graph is similar to the scattergram except that the X values represent a continuous variable, such as time, temperature, or pressure. It plots a series of related values that depict a change in Y as a function of X. Line graphs usually are designed with the dependent variable on the Y-axis and the independent variable on the horizontal X-axis, such as a Kaplan-Meier analyses survival plots of time-to-event outcomes. The proportion of individuals is represented on the Y-axis as a proportion or percentage, remaining free of or experiencing a specific outcome over time.



3.3.3 Bar Graph

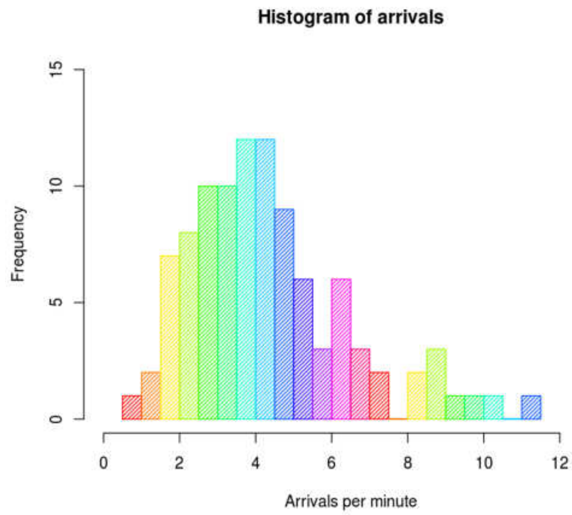
A bar graph may consist of either horizontal or vertical columns. The greater the length of the bars, the greater the value. They are used to compare a single variable value between several groups, such as the mean protein concentration levels of cohort of patients and a control group





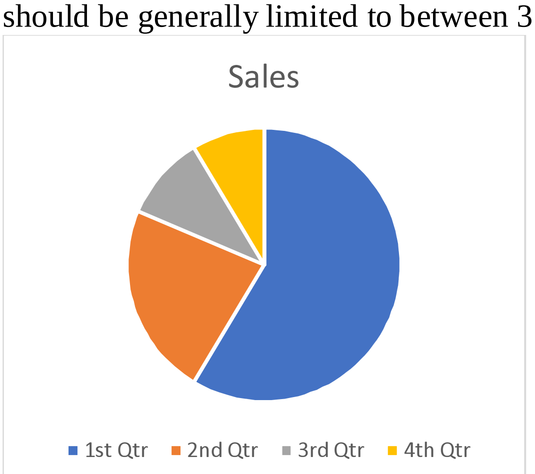
3.3.4 Histogram

The histogram, also called a frequency distribution graph, is a specialized type of bar graph that resembles a column graph, but without any gaps between the columns. It is used to represent data from the measurement of a continuous variable. Individual data points are grouped together in classes to show the frequency of data in each class. The frequency is measured is measured by the area of the column. These can be used to show how a measured category is distributed along a measured variable. These graphs are typically used, for example, to check if a variable follows a normal distribution.



3.3.5 Pie Chart

A pie chart shows classes or groups of data in proportion to the whole data set. The entire pie represents all the data, while each slice or segment represents a different class or group within the whole. Each slice should show significant variations. The number of categories should be generally limited to between 3 and 10.



4.0 CONCLUSION

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.

5.0 SUMMARY

In this unit we learnt that statistics can be very useful in several situations;

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 samples 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.

We also understood graphics and its different forms.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the various types of graphs
2. Highlight the uses of statistics and graphics

7.0 REFERENCE/FURTHER READING

Franzblau LE, Chung KC. Graphs, tables and figures in Scientific publications: the good, the bad and how not to be the latter. J Hand Surg Am 2012; 37 (3): 591-596

Ng KH, Peh WC. Preparing Effective illustrations. Part 1: graphs, Singapore Med J 2009; 50(3):245

UNIT 4 TECHNICAL REPORTS

CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content
    3.1 Definition of Technical Report
    3.2 Report Structure
        3.3.1 Front Matter
        3.3.2 Body of the Report
        3.3.3 End Matter
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

Technical report is an integral part of a soil science research, the ability to write a technical report in a clear and concise manner is a mark of a good soil scientist. A soil scientist must be able translate field research into an understandable written form. A technical report must inform readers of the reasons, means, results and conclusion of the subject matter being reported. The mechanics and format of writing a scientific report may vary but the content is always similar.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Define a technical report
- Highlight the reporting structure in a technical report
- Discuss the main features of;
    a. Front matter
    b. Body of the report
    c. End matter in a report structure

3.0 MAIN CONTENT

3.1 Definition of Technical Report

A technical report (also scientific report) is a document that describes the process, progress or results of technical or scientific research or the state of a technical or scientific research problem. It might also include recommendations and conclusions of the research. Unlike other scientific literature, such as scientific journals and the proceedings of some academic conferences, technical reports rarely undergo comprehensive independent peer review before publication. They may be considered as grey literature.

3.2 Report structure

The report is generally divided into 3 parts: front matter, body of report and end matter. It should be based on the following scheme;

1. Front Matter
a. Front cover
b. Title page
c. Back of the title page
d. Table of contents
e. List of abbreviations, acronyms or terms
f. Preface
2. Body of report
a. Introduction
b. Core of reports
c. Conclusions
d. Acknowledgements
e. List of references
3. End Matter
a. Appendix A
b. Appendix B, etc
c. Indexes
d. Back cover

3.3.1 Front Matter

Front Cover
This part represents the first presentation of the report to the reader, therefore it shall contain the basic bibliographic information to identify the document.

Title Page
The title page of any document is the first recto page of a report and the preferred source of bibliographic information required for efficient document processing and retrieval. Each report should include a title page carrying the following information:

- Full name of the issuing organization and its logo
- *Title of the report* – Titles must be descriptive and ma include subtitles, if any. Concise titles are easier to read than long, convoluted ones. Titles that are too short may, however, lack important information.
- *Authors names and institutional affiliations* – full names of the authors shall be included to avoid any possible ambiguity; the affiliation (i.e. the place where the author works or worked when the report was written) shall be stated according to the official name of the institution.
- *Report identifiers* – They are unique alphanumeric designations that may identify the responsible organization, the report series/collection and the individual report (i.e. Rapporti ISTISAN 05/2 stands for a report of the series *Rapporti* ISTISAN produced in the year 2005 and it is the second report of the year).
- *ISSN/ISBN and other codes* – ISSN is the International Standard Serial Number that is assigned on request by the ISSN Authority (www.issn.org) for reports that are produced in a series; the ISBN is the International Standard Book Number that is assigned on request by the ISBN Authority to each single issue (www.isbn.org). The report may also have other codes, such as DOI (Digital Object Identifier), which may be obtained on request by each authority. More than one code may appear in a report.
- *Place and date of publication* – It is important to include the place and date of publication, both for bibliographic identification and priority concerns. This information may appear in the title page or in the back of the title page.

Back of the title page

The back of the title page should include information also appearing in the title page (report title, authors etc.) and the following items:

- *Abstracts and Key Words* – An abstract should always be included in a report; in the scientific field, two abstracts are recommended: one in English and one in the original language of the report (the translated abstract should be preceded by the translated title). Length and structure of abstracts may vary according to the rules of the issuing organization. Some producers may require structured abstracts or extended ones. The abstract should provide the context or background for the study and should state purposes, basic procedures, main findings, and principal conclusions. It should emphasize new and important aspects of the study or observations. Because abstracts are the only substantive portion of the report indexed in many electronic databases, and often the only portion many readers read.

Abstracts reflect the content of the report accurately. Keywords are also recommended to facilitate information retrieval and assist indexers in cross-indexing.

- *Name and e-mail address of the corresponding author* – It is recommended to facilitate contact and requests of information on the report.
- *Source(s) of support in the form of grants* – If the study described in a report has been funded, information on grants shall be included (at least the name of the funding organization and possibly the contract number)
- *Copyright* – The copyright of the issuing organization shall be clearly indicated proceeded by the symbol © followed by the name of organization and year of publication.
- *Date of submission* – In some cases, it may be useful to include the date of submission for priority concerns.
- *Place and date of publication* – it is important to include the place and date of publication, both for bibliographic identification and priority concerns. This information may appear in the title page or in the back of the title page.
- *Other editorial responsibilities* – All other editorial responsibilities – such as legal requirements, name and address of the printing office, editorial staff names, if any etc. shall be indicated.

Table of Contents

A table of contents (TOC) is essential to provide an immediate understanding of the content of the report. TOC is placed immediately after the back of the title page and contain the titles of the main headings and sub-headings of the report including appendices, if any, together with the number of the pages in which they appear.

List of abbreviations, acronyms or terms

When a report contain many abbreviations or acronyms, they may be listed with their definitions before the body of the report, even though they must be explained in the text when first appearing unless they are standard units of measurement. Only standard abbreviations shall be used since non-standard abbreviations can be extremely confusing.

Preface

A preface may be included or not. If necessary, it shall be placed immediately before the body of the report, and shall contain a preliminary comment on the content of the document and may be signed by a person different from the authors of the report.

3.3.2. Body of the Report

The body of a report is structured according to its content and complexity.

Introduction
Reports may start with an introduction that provides a context or background for the work described (i.e. the nature of the problem and its significance) pointing out specific purposes of the study not including data or conclusions from the work being reported.

Core of report
The core of report represents the main part of the document and shall permit the reader to easily understand its content (theory, methods, results). Topics are presented in logical sequence, the structure of the core depends on the type of the document itself (handbook, research protocol, progress report, etc.). Tables and figures essential to the understanding of the text will be included in the core of the report, but when information is too detailed (i.e. many tables or figures on the same subject) as to interrupt the flow of the text, it shall be presented in the Appendices, which may contain also extra or supplementary materials.

Conclusions
This represents a clear presentation of the deductions made after full consideration of the work reported in the core of the report. It may include some quantitative data, but not too many details. It may also contain recommendations for further actions deemed necessary as a direct result of the study described.

Acknowledgements
It is possible to acknowledge help given in the preparation of the report, but it is not usual to acknowledge minor assistance, routine checking or secretarial work. Major contributions give the right to be included as author of the entire report or of an appendix, if it is the case.

List of references
All sources of information directly used to prepare the text shall be listed at the end of the core of report.

3.3.3 End Matter

Appendices

Appendices are not essential in every report, it can be identified by consecutive letters (Appendix A, Appendix B, etc.). it is used to present material that is necessary for completeness, but would interrupt the flow of reading if inserted in the core of report or material that is not of interest for the general reader.

Indexes

An index, is a list of the main contents or items appearing in a report (such as personal or geographical names, or other topics) arranged in alphabetical order. It is a useful tool for long reports or texts that can be also consulted not in sequence. Indexes represent an added value for the best exploitation of the document and shall be carefully organized.

Back Cover

This can contain the name, address, telephone, fax, e-mail and website of the issuing organization and/or printer and other relevant information on report availability.

4.0 CONCLUSION

A technical report (also scientific report) is a document that describes the process, progress or results of technical or scientific research or the state of a technical or scientific research problem. It might also include recommendations and conclusions of the research. Unlike other scientific literature, such as scientific journals and the proceedings of some academic conferences, technical reports rarely undergo comprehensive independent peer review before publication. They may be considered as grey literature.

5.0 SUMMARY

In this unit we understood;

- What Technical report is
- Reporting structure;
  - Front Matter
  - Body of the report
  - End matter

6.0 TUTOR-MARKED ASSIGNMENT

1. Define technical Report
2. Discuss in sequence reporting structure of a technical report

7.0 REFERENCES/FURTHER READING

International Organization for Standardization. Documentation – Presentation of Scientific and Technical Reports. Geneva: ISO; 1982. (ISO 5966)

European Association of Science Editors. Science editors handbook. Old Working (UK): EASE; 2003;

Gustavii B. How to write and illustrate a scientific paper. Lund: Studentlitteratur;2000

SINGLE Manual. Part I: SIGLE cataloguing rules Luxembourg: EAGLE; 1990

Farace DJ, Frantzen J, editors, GL'97 Conference Proceedings: Third International Conference on Grey Literature: Perspectives on the design and transfer of scientific and technical Information. Luzembourg, 13-14 November 1997. Amsterdam: GreyNet/TransAtlantic; 1993 (GL-Conference Series No. 3).

Guidelines for the production of scientific and technical reports: how to write and distribute grey literature Version 1.0 March 2006

UNIT 5 THESES AND DISSERTATIONS

CONTENTS

1.0 Introduction
2.0 Objective
3.0 Main Content
    3.1 Organizational Sequence
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

A thesis or dissertation is a document submitted in support of candidature for an academic degree or professional qualification presenting the author's research and findings. In some contexts, the word "thesis" or a cognate is used for part of a master's course, while "dissertation" is normally applied to a doctorate.

2.0 OBJECTIVE

By the end of this unit, you should be able to;

- define a thesis/dissertation
- highlight the standard sequence of a thesis/dissertation.
- discuss the standard chapter format for soil science

3.0 MAIN CONTENT

3.1 Organizational Sequence

Standard Sequence

- Cover page
- Fly leaf
- Title page
- Declaration page
- Certification page
- Acknowledgement
- Abstract (Maximum of 300, 500 and 750 words for Project Reports, Thesis and Dissertations respectively)
- Table of content (should reflect only the 1st, 2nd and 3rd tiers of the headings)
- List of figures

- List of tables
- List of plates
- List of appendices
- Abbreviations, definitions, glossary and symbols
- Introductory chapters (introduction, literature review and theoretical framework (as applicable)
- Main chapters (materials and methods/Research Procedures, Results and Discussion)
- Conclusion and Recommendation
- References
- Appendices (if any)

The standard chapter format for soil science is
Chapter 1: Introduction
Chapter 2: Literature Review
Chapter 3: Materials and Method/Theoretical Framework/Research Procedures
Chapter 4: Results
Chapter 5: Discussion
Chapter 6: Conclusion and Recommendation
References
Appendix

Cover Page

The cover page shall indicate (in uppercase only) the:

- Title of the project/thesis/dissertation
- Name of the student (surname last)
- Department/Faculty/University
- Month/Year corrections certified

Fly Leaf

This is a blank page. The white paper used must be of good quality and of the same quality as that on the inside cover.

Title page

The following shall be on the title page (in upper case only)

- Title of thesis/dissertation
- Name of the student (surname last) with qualifications
- Registration number

Followed by

A PROJECT THESIS/DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, (NAME OF UNIVERSITY), IN PARTIAL FULFILMENT FOR THE AWARD OF ____________ (approved name of degree), Department/University, Month and Year of Certification of correction.

Declaration page
Certification page
Acknowledgement
The acknowledgement should contain a brief note of appreciation of all those who contributed to the success of the study

Abstract
The abstract should not exceed 300, 500 and 750 words which approximates, 1, 1 ½ and 2 ½ pages for project reports, theses and dissertation respectively. It should be typed double spaced using Times New Roman characters, font size of 12 and margins justified. Abstract should be brief indicating the statement of the problem, objectives of the work, data collection and analysis, significant findings and conclusions.

Table of content
This is a list of the various sections and subsections of the theses and dissertation and indicating the pages they occur. The table of content should be double spaced. If the title of a section runs more than one line, subsequent lines are single spaced and not indented.
The table of contents should reflect only the 1^{st}, 2^{nd} and 3^{rd} tiers of the headings, where 1^{st} level headings are to be in upper case and bold, 2^{nd} level headings should be in a title case and also bold. Third level headings should not be bold and in a sentence case.

List of Figures, Tables, Plates and Appendices
Where the title of the figure, table, plate or appendix runs more than one line, subsequent lines are single spaced and not indented.

Abbreviations, Definitions, Glossary and Symbols
All abbreviations and symbols used should be explained. Terms used can also be presented as glossary.

Introductory chapters (Introduction, Literature Review/Theoretical Framework (as applicable)

Introduction

A brief review of the research subject is given. The statement of the problem should be well articulated i.e. problems/research questions should be clear and precise.

The introduction should consist of at least

a. statement of the problem.
b. Justification/significance of the study
c. Aim and objectives of the study
d. Research question/research hypothesis

Literature Review

This should be a concise report about the studies of others on the subject matter. It should be logically arranged and up to date. A significant number of the reference ($\geq$70%) should be within the preceding 5 years.

Main chapters (Materials and Methods, Results, Analysis and Discussion)

A detailed itemization of consumable and non consumable materials as well as description of the research methodology should be made. Research/experimental designs, sample and sampling techniques, methodological instruments and equipment; methods of analysis (statistical or otherwise) as well as other aspects of the methodology relevant to the study should be clearly and comprehensively stated.

Data obtained should be well presented and analysis articulated. Major findings should have direct bearing with the statement of the problem and/or research questions.

The Discussion presents explanations of the results obtained in the study. Comparison with existing information/earlier works on the subject should always be made. Justification for disagreements with earlier works should be made.

Summary, Conclusion and Recommendation

The summary should present highlights of the major findings while the conclusions give an inference drawn from the findings. Challenges encountered during the study should be indicated. Conclusions should be drawn on the basis of the data presented and analysed, and policy.

Recommendations should be based on the major findings of the study and stated in precise terms. It should list possible ways of solving problems identified as well as highlight areas for further research.

List of References

This is arranged in alphabetical order of authors' surnames, and chronologically (earliest publication date first) for each author, where more than one work by that author is cited. The author's surname is placed first, followed by initials or first name, and then the year of publication is given. If the list contains more than one item published by the same author(s) in the same year, add lower case letters immediately after the year to distinguish them (e.g. 1983a) there are ordered alphabetically by title disregarding any initial articles (a, an or the).

- The reference list includes only the sources used in any submission. APA style requires reference lists, not bibliographies.
- The reference list begins a new page with the centered heading – References
- Reference list entries should be indented half an inch (five to seven spaces) on the second and subsequent lines of the reference list for every entry – a hanging indent is the preferred style. (i.e., entries should begin flush left, and the second and subsequent lines should be indented)
- Arrange entries in alphabetical order by the surname of the first author as the letters appear (e.g. M. Mac, MacD, Mc).
- If there is no author, the title moves to the author position (filed under the first significant word of the title). If the title in this instance begins with numerals, spell them out.
- States and territories are abbreviated in the location section of the publication information. For U.S. states, use the official two-letter postal service abbreviation (e.g. New York, NY: McGraw-Hill). Spell out country names if outside Australia or the United States.

4.0 CONCLUSION

A thesis or dissertation is a document submitted in support of candidature for an academic degree or professional qualification presenting the author's research and findings. In some contexts, the word "thesis" or a cognate is used for part of a master's course, while "dissertation" is normally applied to a doctorate.

5.0 SUMMARY

At the end of the unit, we learnt about theses and dissertation, the organizational sequence of writing a theses and dissertation. We also learnt the standard chapter format for writing a theses and dissertation for soi science.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define a thesis/dissertation
2. Highlight the standard sequence of a thesis/dissertation.
3. Discuss the standard chapter format for soil science

7.0 REFERENCES/FURTHER READING

Theses and Dissertation Guideline School of Postgraduate Studies, Ahmadu Bello University, Zaria 2015, Ahmadu Bello University Press

UNIT JOURNALS AND THEIR FORMATS

CONTENTS

1.0 Introduction
2.0 Objective
3.0 Main Content
    3.1 Features of a Journal
    3.2 Journals and their Formats
4.0 Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Reading

1.0 INTRODUCTION

A journal is a periodical publication in which scholarship relating to a particular academic discipline is published. Academic journals serve as permanent and transparent forums for the presentation, scrutiny and discussion of research. They are usually peer-reviewed or refereed. Content typically takes the form of articles presenting original research, review articles, or book reviews. The purpose of an academic journal, according to Henry Oldenburg (the first editor of philosophical transactions of the royal society), is to give researchers a venue to "impart their knowledge to one another, and contribute what they can to the Grand design of improving natural knowledge, and perfecting all philosophical arts and sciences.

2.0 Objective

By the end of this unit, you should be able to;

- define a journal
- highlight the features of a journal
- discuss the features of a journal

3.0 MAIN CONTENT

3.1 Features of A Journal

Text: The text of the manuscript, should appear in the following Order;

- Title
- Authors name(s) and address (es),
- Abstract,
- Introduction

- Materials and methods
- Results,
- Tables,
- Discussions,
- Conclusion
- Recommendation(s)
- Acknowledgment
- References,
- Legends,
- Figures and plates

Title page:

The title of the paper should reflect the content and the main theme of the paper. The full names of addresses of authors (including names of institutions and country) should be stated. In the case of joint authorship or multiple authorship, the name and mailing address of the author to whom further correspondence would be referred should be indicated. Authors' names should start with surnames then initials of other names. You can write your title as one statement or use the main/subtitle format For example you can write:

Effect of drought, aging and phophorus status on leaf acid and phosphatase activity in rice

OR you can write

Acid phosphatase activity in rice leaves: effects of drought, aging and phosphorus status

Readers will assume that the subject that comes first in the title is main focus of the paper, so be sure to reflect that in the paper.

There is a third way of writing a title: that is to make a statement:

Acid phosphatase activity in rice leaves is decreased by drought, aging and phosphorus status

This is a very clear approach, almost a mini-summary of the paper.

Abstracts

An abstract represents the contents of the article in short form. There are three types of abstract: informative, indicative and structured: there is often confusion about the words 'Abstract' and 'Summary'. A summary restates the main findings and conclusions of a paper, and is written for people who have already read the paper. An abstract is an abbreviated version of the paper, written for people who may never read the complete version. So a summary is not the same as an abstract, although some journals call the abstracts of the articles they publish 'summaries'.

Informative Abstract

An informative abstract should answer the following questions:

- Why did you start?
- What did you do, and how?
- What did you find?
- What do your findings mean?

The abstract must be written so that it can be read on its own, for example, if it is output from a bibliographic retrieval system. Do not waste words by repeating the title in the abstract. Keep to 250 words or fewer for an article of 2000 – 5000 words, and to about 100 words for a short communication, depending on the journal's requirement's.

If the reason for doing the study is not clear from the title or the rest of the abstract, state the purpose. Say what you studied and what methods you used. Give your main findings concisely and summarize your conclusions.

Indicative abstracts

Indicative abstracts contain general statements describing what is in the text, giving readers a general idea of the contents of the paper, but little, if any, specific detail. They are more common in field reports, long papers such as review articles, and for books or chapters in books.
They are the lazy way of writing an abstract; many journals will ask for a mor informative version.

Structured abstracts

Some journals now ask for an abstract with a specific structure, especially in the medical area, for reports of clinical trials. This sort of abstract is written mostly as a series of points, although the results and conclusion sections should be in sentence form. If your target journal wants a structured abstract. The instructions to Authors will tell you what headings to use and how long the abstract should be.

Examples of a Structured Abstract

Background: The scientific article in the health sciences evolved from the letter form and purely descriptive style in the seventeenth century to a very standardized structure in the twentieth century known as Introduction, Methods, Results, and Discussion (IMRAD). The pace in which this structure began to be used and when it became the most used standard of today's scientific discourse in the health sciences is not well established.

Purpose: The purpose of this study is to point out the period in time during which the IMRAD structure was definitely and widely adopted in scientific writing

Methods: In a cross-sectional study, the frequency of articles written under the IMRAD structure was measured from 1935 to 1985 in a

randomly selected sample of articles published in four leading journals.
Results: The IMRAD Structure, in those journals began to be used in the 1940s. In the 1970s, it reached 80% and in the 1980s was the only pattern adopted in original papers.
Conclusions: Although recommended since the beginning of twentieth century, the IMRAD structure was adopted as a majority only in the 1970s. the influence of other disciplines and the recommendations of editors are among the facts that contributed to authors adhering to it.

Keywords

Keywords or phrases for indexing are often printed at the end of an abstract. If the journal asks for key words. Choose the most important and most specific terms you can find in your paper. Refer to previously published articles in the journal of choice for guidance.

Introduction

This should contain mainly essential background information and important relevant references. The objectives of the work and its relevance or contribution must be clearly stated. The literature cited must be discussed to show the relationships between the published and the research study.

Materials and Methods

New methods and modifications of established ones should be described in detail to enable repetition by other workers. For the established and published methods, references should be made to the relevant publications. Generally acceptable, scientific terms should be used. Discuss the factors, problems encountered and the solutions as they apply to your study. Due attention is given to experimental design, biochemical analyses and biostatistics.

Results

Table and figures are kept to minimum. Each table is typed on a separate sheet of paper. Each table must be numbered in Arabic numerals and should contain brief title on top.

Discussion

This section may be combined with results, one should avoid repetition of methodology and results in discussion, it should indicate clearly the significance and implications of the results obtained. It should also relate to published studies. References should be cited, e.g. Kawo (1999), Adikwu and Arzai (2000), or Kadiri *et al.*, (1997) if there are more than two authors.

Conclusion

Often you will not need to write a conclusions section because you will have already stated your main conclusions in the final section of the discussion. You should certainly never include a conclusion just to repeat what you have said in the discussion. However, if your results and the subsequent discussion have been especially complicated, it may be useful to bring all your findings together.

Acknowledgement

Here you should acknowledge technical help and advice that you received from others. Bodies or individuals granting money that supported either the research or the authors of the paper should be mentioned. Keep this section short.

References

References should be arranged alphabetically, following the APA styles of referencing and the years of publication, only published articles and books and articles 'in press' may be cited. In exceptional cases, citation of personal communication may be allowed. Examples of citations are as follows;

Citation from a Journal

Kadiri, M., Mukhtar, F.B. and Haruna, H. (1997): Responses of some Nigerian Vegetables to growth regulators treatment. *Rev. Biol. Trop*. 45(1): 23-28

Citation from a Book

Mustapha, Y. (1993): An Easy approach to igneous petrology. University of Abuja Press. Nigeria. Pp 20-30

Citation from an Edited Book

Abdullahi, I.L. (1965): The application of trace elements data to problems of petrology In: I.L. Hussain, S.K. Mohmmed and D. Usman (eds). Physics and Chemistry of the Earth. Pergamon, Oxford. PP 133 214.

Citation from unpublished work

Bassey, S.E. (1984): *A gravity study of the lithospheric structure beneath the West African Rift Valley System in Nigeria and Cameroon*. PhD thesis. Department of Soil Science, University of Leeds, England. 132 pp.

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ACADEMIC JOURNALS

Journal of Soil Science and Environmental Management

Full Length Research Paper

Response of food barley (*Hordeum vulgaer* L.) with combined uses of lime and varied phosphorus sources on acidic nitisols of Wolmera District

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A field experiment was conducted on acidic nitisols of Wolmera District in two locations at 2017 cropping season to determine the response of barley for the combined application of lime and different phosphorus fertilizers. Several barley growth performances, yield, and plant samples were collected with soil samples to determine soil acidity attributes and nutrient use efficiency. Barley grain yield and growth performances were significantly ($P<0.05$) affected by the application of different phosphorus sources. The highest grain yield was recorded from NPSB phosphorus fertilizer source in both experimental sites followed by partly acidulated rock phosphate (PARP) with yield improvement of 89 and 52%, over the control treatment respectively. Growth parameters like plant height, spike length, number of tillers, etc., and physical grain quality data (hectoliter weight and thousand seed weight) were significantly affected by all phosphorus sources. The combination of phosphorus fertilizer (NPSB at 69 kg P_2O_5 ha^{-1}) with lime got a higher grain yield advantage over other treatments. The highest phosphorus concentration in the plant parts was recorded from the fertilizer source of NPSB. This was due to its immediate availability to the plant uptake compared to other sources. The use of partly acidulated rock phosphate or organic hyper-phosphate (MOHP) fertilizer, as an alternative for NPSB application provides a competitive yield advantage for acidic soils of Wolmera area or other similar soil type and agroecology of the country.

Key words: Acid soil, food barley, lime, partly acidulated rock phosphate (PARP), organic hyper-phosphate (MOHP), NPSB, yield.

INTRODUCTION

Agriculture is a key driver of Ethiopia's economy and it directly supports 85% of the population, contributes about 40% to the gross domestic product (GDP), and 80% to the export value. However, insufficient productivity of the land for an ever-increasing population has resulted in food insecurity. Soil fertility declines and accompanying

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low levels of agricultural production have been voiced to still be among the serious challenges (Ministry of Agriculture and Rural Development MoARD, 2008). These could be attributed to many factors; complete crop residue removal, low rate fertilizer application, soil acidity, and low use of seeds of improved crop varieties.

Barley (*Hordeum vulgare* L) is one of the most dominant cereal crops widely grown by small-scale farmers under rainfed conditions in the highlands of Ethiopia. It ranks third next to teff and wheat in mid-altitude and first in high-altitude areas in terms of area coverage and production (Central Statistics Agency-CSA, 2016), covering 13% of the total area under cereals. Among several major barley production constraints in the central high land region of Ethiopian soil, fertility limitation takes the lions-role. The national average yield of barley is too low, with a mean of about 2.0 t ha^{-1} (CSA, 2016) due to poor soil fertility (Getachewu et al., 2005). This is true particularly for N and P nutrients due to continuous cropping of cereals and the low level of fertilizer usage (Hailu et al., 1991; Amsal et al., 1997).

Soil acidity is one of the major constraints for the production and productivity of crops in high rainfall areas of Ethiopia. According to the Ethiopian soil information system EthioSIS (2014), acidic soil is estimated to be covering more than 43% of the arable land in Ethiopia of which 13% is strongly acidic (pH < 4.5). Despite these high-level statistics, the situation is not well-understood in detail at the local level, or with more up-to-date estimates of severity (IFPRI, 2010). Different human and climatic factors have contributed to soil acidification in Ethiopia including erosion, nutrient and organic matter depletion due to continuous cropping and residue removal along with the presence of high precipitation that leads to basic cation leaching (Mesfin, 1998). The process of acidification results from the replacement of basic cations Ca, Mg and K in the soil exchange sites with Al, Mn and Fe and increased the concentration of H^+ ion in the soil solution. Where soil pH is lower than optimal (5.5 and below), the availability of nutrients needed for growth is reduced.

This condition also usually leads to Al and Mn toxicity plus a deficiency in N, P, K, Mg, Ca and Mo. This has multiple effects for the plant growth and nutrient management as this leads to lack of or reduced response to applied fertilizers due to high P fixation by oxides of Al and nutrient deficiency which can result in 50% and above yield reduction (IFPRI, 2010).

To improve acid soil related production problems, soil and crop management effort has been the main important research and development agenda in the country since 2006 (Soil Sector Strategy). Liming with calcium carbonate ($CaCO_3$) is generally the first management practice that comes to mind when the question of high phosphorus fixation in acid soils is raised (Alemayehu et al., 2017). Thus, lime with P application on acid soils has been among the interventions widely studied on th performance of major crops in different agro-ecologies.

Crop management components along with lime incluc the use of fertilizer, improved seed and agronom practices. Above all, long-term experiments als emphasize the need for greater use of fertilizers (miner and organic) to remedy the nutrient deficiencies in Afric (Bekunda et al., 1997). The work of Shiferaw ar Anteneh (2014) have also indicated that half dose recommended lime application with NPK fertiliz significantly increased barley yield both at Alisols Chencha and Luvisols of Hagereselam indicating th balanced fertilization of acidic soils is critical f sustainable crop production. For intensive ar continuous crop production, these inputs should aim balanced utilization of nutrients along with the efforts maintaining the soil pH at an optimal level by limir (FAO, 2000).

In spite of the need for balanced fertilization in acid so along with lime, only N and P have been applied widely the form of Urea and DAP (diammonium phosphate) as high-grade fertilizer in order to obtain optimum harvest the Wolmera district of Ethiopia. Regardless of th blanket application of these nutrients and unbalance fertilization of the soil application per hectare in Ethiopi it has increased five times since the 1980s and is bett than the sub-Saharan Africa average (IFPRI, 2010). Th indicates the increased demand for inorganic fertilize uses by Ethiopian farmers to maximize their productivit Consequently, unbalanced fertilizer use has resulted widespread multi-nutrient deficiencies in Ethiopian soi (Mesfin, 1998). Thus, lime technology must consider th application of both macro and micro plant nutrien because if any nutrient is deficient, it will affect both cro yield and quality, as well as nutrient use efficiency other applied plant nutrients.

Very recently, however, this generalized and ove simplistic driven fertilizer recommendation approach ha been replaced by balanced fertilizer and site-specif nutrient deficiency-based schemes. The EthioSIS (201 soil fertility map has provided basic data for balance fertilization research in major Ethiopian soils. To th effect, different fertilizer blends have been evaluated f their effectiveness in addressing site-specific deficienc and improving nutrient use efficiency and productivi across different agro-ecologies and soil types (Getachev 2005). In line with this, correcting the nutrient deficienc and imbalance through suitable fertilizer type and nutrie composition is very important in low pH soils in order improve the lime affordability and adoptability th enables the split application of bulky recommended ra while maintaining the crop performance.

Therefore, the objective of this study was to assess th effects of lime, different phosphorus fertilizer sources ar their appropriate combined application rates on grow performance, grain yield and quality of food barley Wolmera district and similar agro-ecologies.

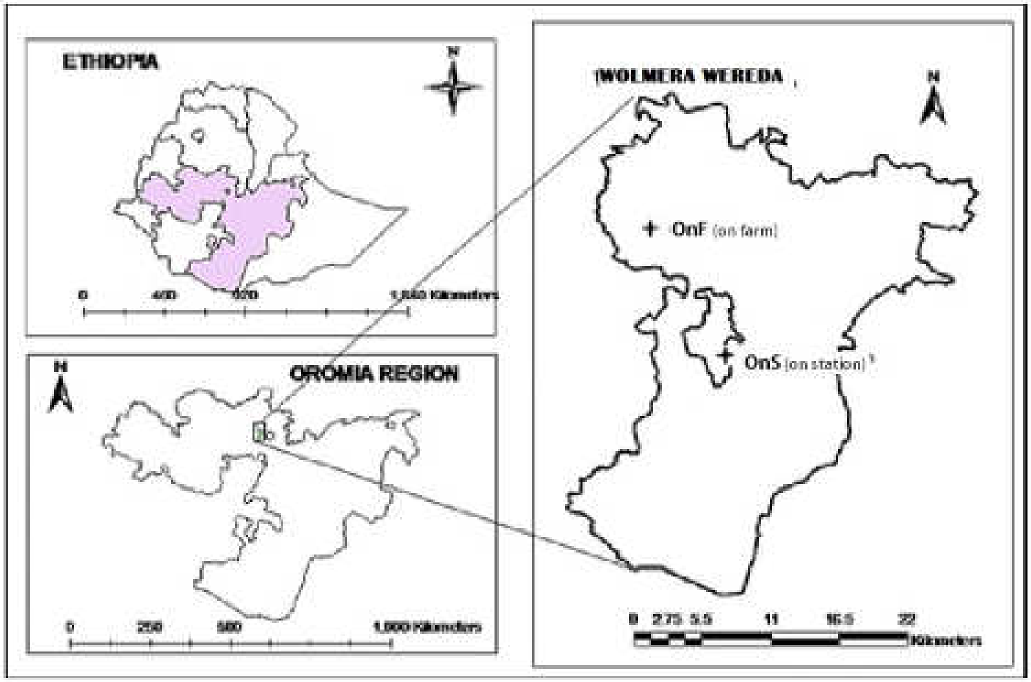

Figure 1. Location of the study area at Holeta Agricultural Research Center or on-station (OnS) and Rob Gebeya kebele on farmer's field or on-farm (OnF) in Wolmera district, Oromia Regional State.

MATERIALS AND METHODS

Description of study area

Field experiment was conducted in Wolmera district at two locations, viz: at Holeta Agricultural Research Center Farm (OnS) and on farmer's field (OnF) at Rob-Gebeya kebele in the central highland of Ethiopia, west of Addis Ababa (Figure 1). The experimental sites were geographically located at DMS (degree minute second) georeferenced coordinate units:

1. On-Station (OnS): at 9^{0}.03'.15.6" N latitude; 38^{0}.30'.07.04" E longitude with mean altitude of 2365 masl
2. On-Farm (OnF): at 9^{0}.08'.24.7" N latitude; 38^{0}.26'.07." E longitude with altitude 2625 masl.

Wolmera District is one of major barley producer districts in the Oromia Regional State of central Ethiopian highland, which is part of the Oromia Special Zone Surrounding Finfinne (Addis Ababa). It is bordered to the south by Sebeta Hawas, to the west by West Shewa Zone, on the north by Mulo district, to the northeast by the Sululta city and on the East by the city of Addis Ababa.

From the recent five years (2013-2017 inclusive) weather records for Holeta Agricultural Research Center, it was observed that a mean annual air temperature of 14.6°C that varies from 5.6°C minimum monthly average up to 23.4°C monthly mean maximum temperature. The absolute monthly mean maximum of 28.6°C and minimum of -0.6°C occurred in January and March 2013 respectively. The average sunshine hours are 6.6 h/day in a year and this varies between 2.7 h/day in July and 9.1 h/day in November. Holeta area receives an average total rainfall of 919.4 mm annually, whereas in the study year (2017), 1071.6 mm rain was registered (Figure 2). This is spread over all months except December and ranges from the lowest of 0 mm in December to the highest of 311 mm in August 2017.

Barley (*H. vulgare* L.) was used as test crop for this study, which is one of the most important cereal crops widely grown by small-scale farmers under rain fed conditions in most highlands of Ethiopia. It has suffered from soil acidity more than other major cereals dominantly grown in the study area. Food barley (*H. vulgare* L.) variety BH -1307, which is the most widely acceptable variety in Wolmera areas with a yielding potential ranging from 3000-5000 kg ha^{-1} requires an average number of 137 days to mature with 81 days of heading under ideal environmental condition for production (Bayeh and Stefania, 2006).

Experimental design and treatments

The experiment was conducted using randomized complete block design (RCBD) in factorial arrangement. Four different types of phosphorus fertilizer sources: partly acidulated rock phosphate (PARP), Organic hyper-phosphate (MOHP), NPSB blended fertilizer (formula II) and NAFAKA+ represented by (P1, P2, P3 and P4

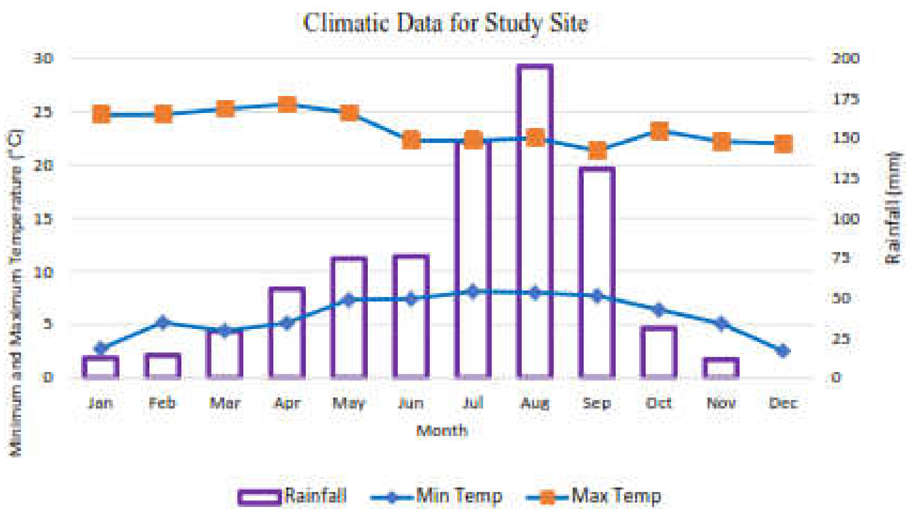

Figure 2. Five years mean climatic data for Holeta Agricultural Research Center taken from center weather station (2013-2017). Major axis at the left side was used for max and min temperature while the minor axis at the right side was used for Rainfall.

Table 1. Chemical composition of different phosphorus sources used for the study.

No.	Phosphorus source	Symbol	Chemical composition (%)							
			N	P_2O_5	K_2O	S	B	Zn	CaO	MgO
1	Partly acidulated rock phosphate	PARP (P1)	-	49	-	7	0.6	2	-	-
2	Organic hyper-phosphate	MOHP (P2)	-	26	-	-	-	-	36	-
3	Formula II	NPSB (P3)	16.1	36.1	-	6.7	0.71	-	-	-
4	NAFAKA plus	P4	9	16	16	5	0.1	0.5	25	2

respectively). Phosphorus fertilizer rates (PR1 half recommended P rate 34.5 P_2O_5 kg ha^{-1} and PR2 fully recommended P rate 69 kg P_2O_5 ha^{-1}) and lime rates (0 lime and 1/4th of LR computed from EA soil exchangeable acidity result for each experimental site) are used with three replications (Table 1). As a control treatment, no input application was used for comparison purposes. Reduced lime rate 1/4th from the required was used since most of P sources have their own incorporated lime. Likewise, liming effects of some P sources which have incorporated $CaO/CaCO_3$ (Table 1) were taken. Different sources of P-fertilizers used are listed below with their chemical composition from P1 up to P4.

In all treatments, major essential nutrients were kept at the same rate except phosphorus (P_2O_5) by using independent sources which does not exist from single granule of phosphorus fertilizer sources (Table 2). Nitrogen, potassium, sulfur and boron are kept at the same rate for all treatments by using fertilizer sources like: Urea CO $(NH_2)_2$ 46% N, Muriate of potash (MOP) KCl 60% K_2O, Ammonium sulphate $(NH_4)_2SO_4$ 21% N and 24% S and Borax ($Na_2B_4O_7.10H_2O$) 11% boron respectively used as other sources of essential nutrients to reduce the confound effects from other nutrients than phosphorus between treatments.

Recommended fertilizer rate for barley production in Wolmera area from the previous study were 69 and 60 kg ha^{-1}, P_2O_5 and N respectively (Bayeh and Stefania, 2006). Depending on EthioSIS soil fertility map (2014), deficient plant nutrient type and recommended fertilizer formulation were determined as NPSB (Figure 3). The application rate of S and B fertilizer was fixed according to the recommended rate of NPSB (Formula II) based on P_2O_5 content. Zn is eliminated since it was not found to be limiting nutrient in both experimental sites as soil fertility map of the Woreda and preliminary soil test results confirmed.

EthioSIS (2014) soil fertility map determines that the blended fertilizer rate combination for Wolmera district specific study site was computed from a combination of NPSB with 69 kg P_2O_5 ha^{-1}. This was computed from blended fertilizer formula II /NPSB at 191 kg ha^{-1} (114 g $plot^{-1}$) application combined with 55 kg ha^{-1} (33 g $plot^{-1}$) urea (Table 3). From total application rate of 191 kg ha^{-1} NPSB fertilizer, we have nutrient contents (P_2O_5= 69 kg ha^{-1}; S=12.4 kg ha^{-1}; B= 1.4 kg ha^{-1}). Thus, other phosphorus fertilizers rate was fixed with these nutrients rate and applied at once while planting is done with band application method, except for urea which is applied in two splits.

Table 2. Treatments description for the effects of lime and different P-source on food barley at Wolmera district.

Experimental factors	Description
Factor 1	- P1= PAPR* - P2= MOHP* - P3= NPSB (Formula II) * - P4= NAFAKA Blend plus*
Factor 2	- PR1= Half dose of recommended P- fertilizer rate (34.5 kg ha^{-1} P_2O_5). - PR2 = Full dose of recommended P - fertilizer rate (69 kg ha^{-1} P_2O_5).
Factor 3	- LM1= Without lime application. - LM2= With lime applied depending on soil initial EA result.

*All required N, K, S and B were added to all P treated plots to avoid the partial treatment effect of some P sources; Zn was not considered since they are found with sufficient level EthioSIS (2014); EA is exchangeable acidity.

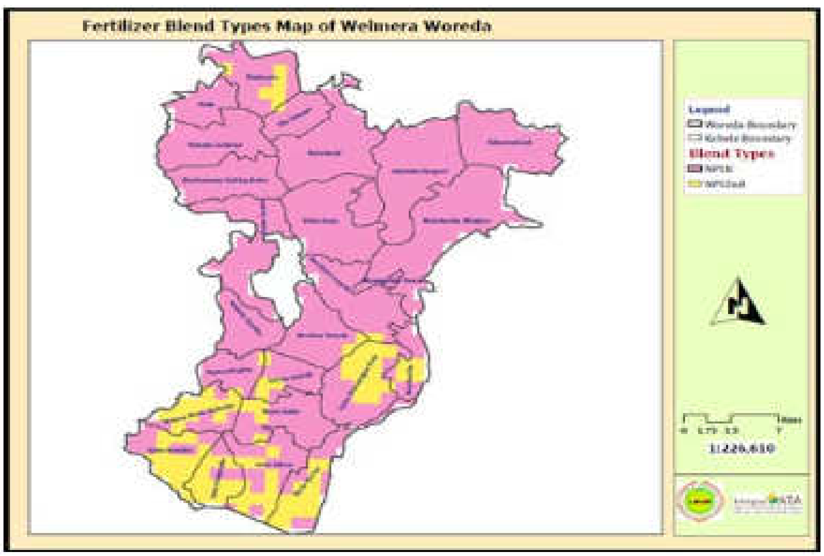

Figure 3. Ethiopian soil information system digital soil fertility map of Wolmera Woreda and its Kebeles in detail with their recommended fertilizer type.
Source: EthioSIS (2014).

Lime requirement (LR) rate determination

The amount of lime required to reclaim each study area acidic soil was determined by using exchangeable acidity method (Kamprath, 1984).

$$LR, CaCO_3\,(kg/ha) = \frac{[cmol\,(EA/kg)\text{ of soil} \times 0.15\text{ m} \times 10000\text{ m}^2 \times B.D\,(g/cm^3) \times 1000]}{2000} \times Factor \quad (1)$$

Where 0.15 m is the plow depth; 10^4 m^2 is area for 1 ha of land; B.D is bulk density of the soil multiplied by 1000 to convert g cm^{-3} to kg m^{-3}.

The required lime computed for on-station and on-farm experimental sites were 733.5 and 1127 kg ha^{-1} $CaCO_3$ respectively; thereafter 1.5×LR was used as multiplying factor for cereal crops, which eventually results to 1100 and 1691 kg ha^{-1}. For this experiment, 1/4th of LR was used, making the final amount of lime which was

Table 3. Application rate of different P source of fertilizer and other essential nutrients for each treatment.

Treatment No.	P sources (kg ha^{-1})				Other nutrient sources (kg ha^{-1})			
	PARP	MOHP	NPSB	NAFKA+	*N from $CO(NH_2)_2$*	*S from $(NH_4)_2SO_4$*	*B from Borax*	*K from KCl*
1	-	-	-	-	-	-	-	-
2	70.4	-	-	-	115.4	31.1	6.89	43.2
3	140.8	-	-	-	126.3	6.92	5.05	43.2
4	-	123.2	-	-	106.7	51.7	12.7	43.2
5	-	246.4	-	-	106.7	51.7	12.7	43.2
6	-	-	95.5	-	83	-	-	21.5
7	-	-	191	-	55	-	-	43.2
8	-	-	-	215.5	86.3	-	-	-
9	-	-	-	431	45.6	-	-	-

Control treatment was included for different comparisons, that is, Treatment #1. All rates are given as a total bulk weight of each fertilizer source 3.

applied for those experimental sites to be 275.1 and 422.9 kg ha^{-1}, respectively. This reduced amount of lime rate is due to split application of lime where full dose of required lime is applied in four successive years which is widely practiced by small scale barley producer in the study areas. Consequently, for single cropping season, we used full dose of lime requirement rate, showing effects for at least five consecutive years, hence it needs to be reduced to this amount in addition to liming effects of some phosphatic fertilizer used for these study. It was applied 3 weeks before planting using quick lime (CaO) as a liming material which has 179 calcium carbonate equivalence (CCE). Therefore, lime requirement (LR) from $CaCO_3$ source is multiplied by 0.559 to find the CaO amount required for final application rate.

All fertilizer treatments were applied with band application method at planting except nitrogen sources (urea) which is applied into two splits first at planting and the 2nd at tillering growth stage of the barley crop. Planting was done on July 7th and July 12th, 2017 for OnS and OnF trials respectively using row planting with spacing of 20 cm between rows on plot size of 2 m × 3 m.. The two border sides were rejected in each experimental plot and the inner 13 rows were taken for all kinds of agronomic data collected from the plants. The seed rate used was 100 kg ha^{-1} (for both experiment sites). Spacing between treatments and replications were kept at 0.5 m and 1 m respectively. The testing site was geo-referenced to generate area specific micro nutrient deficiency information and to produce the micro nutrient blends.

Weed control is done by hand, with weeding frequency of two times for each experimental site. While the first weeding was done at tillering plant growth stage, the 2nd weeding was done before booting growth stage of the barley crop. Several types and intensity of diseases were found to occur during the growing season with the majorly identified ones including: Scaled (*Rhinchosporium secalis*), Net Bloch (*Pyreno phorateres*) and leaf rust (*Puccinia hordei*) diseases observed specially in on-station experimental site. All disease incidence, severity and plant reaction data to the occurred disease was recorded for each experimental unit.

Data collected

Crop phenology and growth parameters

Agronomic data like plant height, spike length, number of spikelets per spike, number of effective and total tiller were collected about the experimental crop like date of flowering (at >75% of plant population flowering in each experimental plot), date of maturity, average plant height (PH) from sample plants, mean spike leng mean number of spikelets per spike, number of total tiller a effective tillers per plant, as well as total biomass at harvesting w collected from all experimental units.

Plant height: This was taken when crop attain maximum height crop maturity growth stage. Data was taken from 10 rando experimental sample plants. It measured from the ground level to higher tip of the plant by using height meter and the mean resu were presented in centimeter measurement unit.

Total number of tiller per plant: During random harvestir selected sample plants were uprooted and the number of tille which was raised from single plants were counted, wheth productive or not and the average values were taken for each pl Number of effective tiller per plant is the same as total number tiller per plant except that it considers only tillers which set grain with effective spike.

Spike length and number of spikelet per spike: This was tak as the average spike length value measured from ten rando sample plants at maturity which were taken for all agronomic da measurement and it is measured in centimeter unit. Similarly, t spike samples were taken from the sample plants at harvesting, t number of seeds in each spike was counted, and the avera number of spikelets was taken as representative data for ea experimental plot.

Date of flowering/booting and maturity: Data was taken wh more than 75% of plant population was flowers set in ea experimental plot. It used to identify each treatment and how respond to different inputs by comparing with standard number days required by specific variety of barley and to compa treatments responses on delayed or forced maturity depending the input variability. Maturity date was taken as the required numb of days to attain plant physiological maturity stage of more th 75% of plant population in each experimental plot.

Yield and its components

Dry above ground biomass AGB and grain yield GY were collect from each experimental unit independently for each experimen unit.

Above ground dry biomass (AGB): This was collected using sa in plot base at harvesting. It was taken from middle experimental rows of barley as fresh total biomass. After drying at thrashing time, it was taken as dry above ground biomass yield for all experimental plots.

Grain yield (GY): After threshing the harvested crop, grain yield obtained from each experimental plot were taken by sac and weighted with their moisture percentage using digital balance and moisture tester. Finally, the grain yield was converted into kg ha^{-1} by adjusting to 12% gain moisture level.

Grain physical quality data like thousand seed weight and hectoliter weight was taken beside grain nutrient analysis. Hectoliter Weight (HLW)/Test weight, also known as hectoliter mass, is a measure of the volume of grain per unit. It is usually expressed as kg per hectoliter and is a good indication of grain-soundness. Millers usually use test weight as an indication of expected flour yield. It was done by taking 1 kg clean seed sample, grain samples were inserted into the measuring device and results read.

Thousand seed weight (TSW): This was measured by using seed counter and TSW measuring device. Collected grain sample from each experimental plot was determined for their TSW result found from the measuring device.

Grain moisture percentage (MST): This was collected for grain yield weight adjustment measured using HLW meter.

Plant and soil sample collection, preparation and analysis

Plant samples (straw and grain samples) were collected finally at threshing and winnowing which includes grain and all the remaining above ground plant part (straw) in separate sample from each experimental unit. The straw and grain samples were milled and sieved through 0.5-mm size sieve. Prepared sample were tested under HARC plant and soil analysis laboratory. Samples were tested for their P, N and S concentration within the plant biomass.

Soil sampling and analysis

Several soil samples were randomly taken at surface (0-20 cm depth) to assess the physicochemical properties and the dynamics of the study soils during the field experiment. Fifteen samples were collected before experiment was set up and then bulked into one composite, while after the experimental crop was harvested, soil samples were collected treatment-wise to evaluate the effect of treatments on major soil acidity attributes like pH and exchangeable acidity and to assess the residual effect of the treatment application on soil physicochemical properties.

Physical property determination: Soil sample collected from the study area was examined for its textural class by using hydrometer method of soil particle size distribution determination at HARC soil and plant tissue analysis laboratory. The soil bulk density (apparent density) of the study site was determined by taking core sample from each experimental site and using undisturbed method of BD determination.

Chemical property determination: Determination of soil pH is done by H_2O method with 1:2.5 ratio soil to water suspension; Exchangeable acidity (EA) of the study area soil sample was determined by using Van Reeuwij k, L.p 1N KCl leaching titration method (Sarkar and Haldar, 2005). Organic carbon (OC %) was determined by using Walkley-Black chromic acid wet oxidation method (Sarkar and Haldar, 2005). Total nitrogen (TN) was determined by using Kjeldhal Bremner and Mulvancy method. Soil extractable P (Brey II method was used which is the same as Bray I procedure of extractable P determination except that the concentration of HCl in Bray II is increased to 0.1 N from 0.025 N. It is appropriate for acidic soil and for soil samples where RPs are used as P fertilizer. Cation exchange capacity (CEC) was determined by using ammonium acetate extraction method whereas soil available sulfate-sulfur (SO_4-S) was determined by using turbidimetric method (Sarkar and Haldar, 2005).

Composite soil sample from both experimental locations was analyzed for their basic cations, that is, exchangeable potassium (K^+), Magnesium (Mg^{2+}), Sodium (Na^+) and Calcium (Ca^{2+}) by using ammonium acetate method of extraction which is appropriate for acidic to slightly alkaline soil types. Then the extract was read using instruments, for K^+ and Na^+ Flame Emission Spectro Photometer (FESP); and for determination of Ca^{2+} and Mg^{2+}, Atomic Absorption Spectro Photometer (AASP) apparatus was used. Boron (B) was determined using dilute hydrochloric acid method which is more suitable for acidic soil types (Sarkar and Haldar, 2005).

C:N ratio indicates the general process undertaken in the soils of study site related to N during decomposition of OM and effectiveness of applied N fertilizers to crop utilization. It was computed by directly taking the result of C and N in the examined soil sample; Percent acid saturation (PAS) of the soil was computed from the ration of exchangeable acidity (EA) to the CEC multiplied by 100 which is the part of cation exchange site occupied by the H^+ and Al^{3+} ions that contributes to the EA properties of soil (Fageria et al., 2007).

Economic analysis

Partial budget analysis

Economic analysis was done for each treatment through evaluation of cost and return, and benefit to cost ratio was calculated according to the procedure given by CIMMYT (1988). Variable input was identified for each treatment which requires different input and labour costs for its practical implementation on farmers' field in hectare bases. It includes lists of variable input data related to price of lime, different types of P fertilizers and other sources of essential nutrient used, cost incurred for transport, labor cost for field managements and application of those inputs and land preparation. The price of barley grain and straw after harvest were taken into account to undertake cost-benefit analysis. The marketable grain and biomass/straw yield from the control plot (no lime and fertilizer input) was taken as a reference and the yield increment at different treatments that received different type and rates of input was considered for evaluation. The average market price of barley grain and straw yield in the local market of the area was 1000.00 and 35.00 ETB Qt^{-1} respectively. The minimum acceptable marginal rate of return used in this study was assumed to be 50% for farmers' recommendation domain. Finally, the treatment that gave the maximum benefit cost ratio was selected. The economic analysis was based on the formula developed by CIMMYT (1988).

Average grain and biomass yield (AGY and ABY) (kg ha^{-1} or t ha^{-1}): Is an average grain and biomass or straw yield of each treatment since both of them are the marketable products.

Adjusted grain and biomass yield (AJG and AJB): Is the average grain and biomass yield adjusted downward by 10% to reflect the difference between the experimental yield and yield of farmers.

AJG= AGY - (AGY × 0.1)

AJB = AJB – (AJB × 0.1)

Gross field benefit (GFB): This was computed by multiplying field/farm gate price that farmers receive for the grain and straw

Table 4. Physico-chemical properties of both experimental site soil samples before planting (treatment application).

Location	pH	TN (%)	K Cmol (+) $kg^{-1}s$	AP (ppm)	Mg Cmol (+) $kg^{-1}s$	OC (%)	Ca Cmol (+) $kg^{-1}s$	Na Cmol (+) $kg^{-1}s$	EA Cmol (+) $kg^{-1}s$	CEC (meq/100 g)
OnS	5.14	0.143	1.262	4.36	4.01	1.13	6.6	0.145	0.978	19.6
OnF	4.24	0.134	1.976	7.86	4.67	1.76	8.3	0.0825	1.367	27.4

TN= total nitrogen, AP= available P, OC =organic carbon, EA= exchangeable acidity, OM= organic matter. Meq 100 g^{-1} soil = Cmol (+) kg^{-1} of soil.

yield when they sell it as adjusted yield.

GFB = (AJG × Field/Farm gate price of barley grain) + (AJB × Field/Farm gate price of straw)

Total cost (TC): is the cost of inputs used in the experiment as mean current prices of lime, different types of fertilizer, wage for lime and fertilizers application, and transport were considered per hectare.

Net benefit (NB): This was calculated by subtracting the total costs from the gross field benefit for each treatment.

NB = GFB – TC

Marginal cost (MC) = Change in costs between treatments.

Marginal benefit (MB) = Change in net benefits between treatments.

Dominance analysis: This is done by sorting total variable cost of each treatment in ascending order and then computing the difference in cost (C) and benefit (B) of each successive treatment as described in CIMMIT (1988) procedure to calculate the marginal rate of return and treatments dominance. Any treatment that has net benefits which are less than or equal to those of a treatment with lower costs that vary is dominated (Stephen and Nicky, 2007).

Marginal rate of return (MRR): The process of calculating the MRR of alternative treatments, sorted from the least costly treatment to the costliest ones, and deciding if they are acceptable to farmers, is called marginal analysis; in other words, it is the slope of net benefit curve between two successive treatments. %MRR was calculated as changes in net benefit (raised benefit) divided by changes in cost (raised cost).

% MRR = (MB / MC) × 100

Statistical analysis

Agronomic data, grain quality parameters and plant tissue analysis results were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS version-9.0) to evaluate the impact of different P fertilizer source with different lime and fertilizer application rates. Results were presented as means with Least Significance Difference (LSD) at 5% probability level (Steel et al., 1997). Over location combined data of some parameters was done since largest standard error SE to least SE ratio was below 3 which indicates its homogeneity across experimental locations (Gomez, 1984).

RESULTS AND DISCUSSION

Preliminary soil physico-chemical properties of study area

The soil analysis results of the study areas showed that N, P, S and B were more limited than other essential mineral nutrients (Table 4) as confirmed by EthioSIS, (2014) soil fertility map, whereas the remaining essential mineral nutrients are found relatively in higher and sufficient levels.

Soil physical properties

The mean soil particle size distribution results for each composite soil sample was 50% clay, 18.8% silt and 31.3% sand for on-station site (OnS) which is classified as "Clay" textural class (Table 4) whereas the on-farm site (OnF) had an average content of 37.5% clay, 20% silt and 42.5% sand. Consequently, it was grouped as the "clay loam" textural class (USDA, 2008). Both study sites soil physical properties were categorized under fine texture class, much influenced by their higher amount of clay particles, which in turn influences the physical and chemical properties of such soils. Thus, organic inputs application influences its erosion response and physical environmental impacts. It also has several impacts on the P fixation, nutrient holding capacity, buffering capacity and other chemical properties related to productivity of such soils (Morel et al., 1989).

Soil chemical properties

For OnS samples, the mean pH reading was 5.14, which is categorized as 'strongly acidic property according to USDA/NRCS (1998) rating, while for the OnF, the average pH was 4.24, which is virtually the same category with the OnS with their soil pH results. Mean exchangeable acidity (Al^{3+} and H^{+}) results for both locations soil samples were 0.978 and 1.367 Meq 100^{-1} g of soil for OnS and OnF site respectively (Table 4) which are quite representative for soil acidity. The OnS site EA level exceeds by 1 Meq 100^{-1} g of soil. As reported by several authors, soil pH value with <5.5 usually have problems of Al toxicity or acidification, but can be improved by amendment practices like application of lime, compost or organic manure (Scherr and Yadav, 1996). Upon liming, Alvarez et al. (2009) reported decreases of Al^{+3} in the soil solution as well as in the exchangeable complex which creates conducive soil environment for potential crop production.

Available P (AP ppm) for OnS and OnF sites were 4.34 and 7.85 ppm respectively. The level of AP in each study

Table 5. Major barley growth parameters as affected by different P sources of fertilizer, P rate, lime application and location sources of variability.

Source of variability		PH (cm)	SPL (cm)	NSK	TT	ET	DF	DM
Location	OnS	101.41	7.2^{A}	46.9	5.17^{A}	4.34^{A}	96.13^{A}	135.7
	OnF	101.41	6.6^{B}	46.7	4.17^{B}	3.16^{B}	85.2^{B}	135.6
LSD		Ns	0.16**	Ns	0.47**	0.39*	3.4**	Ns
P Sources	PARP	100.6^{B}	6.90	47.2	4.4^{B}	3.49^{B}	92.7^{B}	133^{BC}
	MOHP	101.7^{AB}	6.99	47.5	4.3^{B}	3.35^{B}	96.7^{A}	138.3^{AB}
	NPSB	103.7^{A}	6.78	45.7	5.6^{A}	4.65^{A}	75.4^{C}	139.7^{A}
	NAFAKA+	99.5^{B}	6.90	46.8	4.4^{B}	3.51^{B}	99.9^{A}	131.4^{C}
LSD		2.68 *	Ns	Ns	0.67*	0.55**	4.8**	5.41*
P. Rate	34.5 kg ha^{-1}	101.4	6.87	46.4	4.5	3.56	93.2	137.2
	69 kg ha^{-1}	101.5	6.92	47.2	4.6	3.92	90.1	134.1
LSD		Ns	Ns	Ns	Ns	Ns	Ns	Ns
Lime	LM1	101.2	6.79^{B}	45.6^{B}	4.2^{B}	3.39^{B}	90.5	134.3
	LM2	101.6	7.0^{A}	47.9^{A}	5.1^{A}	4.10^{A}	92.9	136.9
LSD		Ns	0.16 *	1.3 **	0.47**	0.365*	Ns	Ns
Control		92.7	6.47	43.5	3.9	3.1	107.2	149.5
CV (%)		4.6	5.6	7.05	24.6	25.2	9.1	6.9

Means with the same letters have no significant difference b/n each other Ns not significant, * significant at $P<0.05$ ** highly significant at $p<0.01$ and *** significant @ $P<0.001$. PH plant height in cm, SPL spike length, NSK number of spikelets per spike, TT total number of tillers per plant, ET effective tiller per plant. DF, DM- date of flowering and maturity respectively.

plant by decreasing Al toxicity rather than by affecting soil P availability percent (Hynes and Ludecke, 1981) which busts the barley productivity by enhancing the metabolic activity for proper physiological maturity. On the other hand, an application of different sources of P fertilizers MOHP with application rate 69 kg ha^{-1} P_2O_5 gave higher number of spikelets.

Number of days to flowering and maturity

The preferable result in date of flowering (DF) and date of maturity (DM) parameters were identified as the treatment which requires moderate ranges of days depending on the barley variety used whether it is late set or early set (the right/optimal number of days required to flowering and maturity for barley BH-1307 variety is 80 and 135 days respectively as specified in the variety description). Accordingly, application of different sources of phosphorus fertilizer and different experimental locations sources of variability significantly ($p<0.05$) influenced the number of days required for flowering and maturity in more than 75% of plant population within each plot in appropriate time. 75.4 days to flowering was required by NPSB blended fertilizer P source which approaches varieties optimal requirements.

On the other hand, DM (number of days to maturity) was significantly ($P<0.05$) affected by application of diversified sources of P fertilizers. Both delayed and forced maturity was observed in some of the experimental units due to different treatment factors majorly induced from nutrient deficiency/imbalance and limitation effects on their nutrient use efficiency. Accordingly, the optimal DM was obtained from MOHP and NPSB sources of phosphate fertilizer with 138.3 and 139.7 average number of days respectively (Table 5). Getachewu (2005) also showed that P fertilizer application improves number of days required to heading and maturity of barley crop.

Effects on biomass, grain yields and grain physical qualities of barley

Above ground dry biomass

Above ground dry biomass (AGB) of barley was significantly ($p<0.05$) affected by phosphorus fertilizer

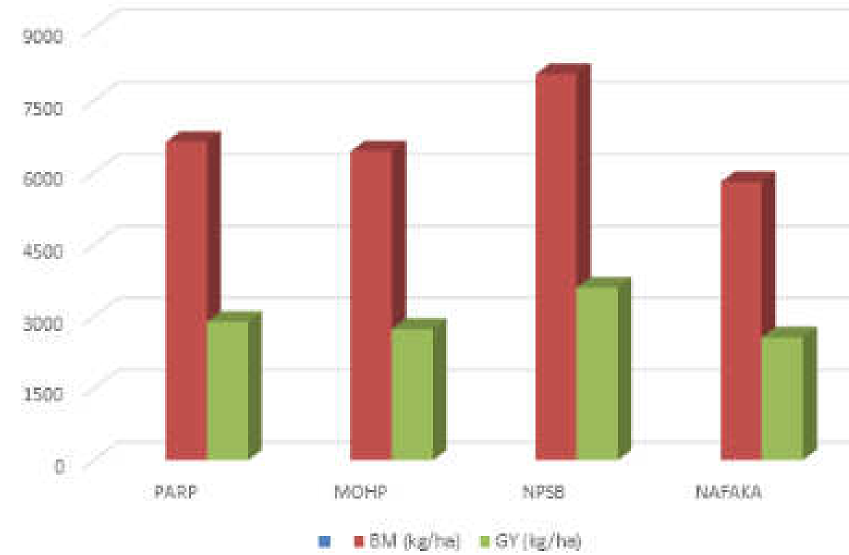

Figure 4. Grain and biomass yield of barley crop as affected by different sources of phosphorus fertilizers in Welmera district.

support the finding of Ester et al. (2014) who could observe different crop performance in response to different sources of Phosphorus fertilizers application. Indeed, the available or water soluble P_2O_5 content was varied to provide immediate use and gradual release of P in available forms to plant uptake. This improves suitable supply for the crop uses instead of fixation by such acidic soils into unavailable forms. The competitive result obtained from PARP fertilizer supports the findings of Chien and Menon (1995) in which several field trials conducted by IFDC in Asia, sub-Saharan Africa, and Latin America have demonstrated that PARP at 40-50% acidulation with H_2SO_4 or at 20% by H_3PO_4 approaches the effectiveness of SSP/TSP (high-grade water-soluble P sources of fertilizer) in certain tropical soils and crops.

Lime application at LM2 rate produced significantly ($P<0.05$) higher GY (3025.2 kg ha^{-1}) as compared to un-limed LM1 treatment average GY (2842.5 kg ha^{-1}) result (Table 6) which was also reported by Meng et al. (2004) in which significant yield increment were obtained using lime on acidic soils. On the independent result of each experimental site, at OnS, superior GY (4746.7 kg ha^{-1}) resulted along with other most agronomic parameters when NPSB was applied at 69 kg ha^{-1} P_2O_5 treated with lime. This is approximately the maximum yield potential (that is, 30-50 Qt ha^{-1}) of food barley variety BH-1307. Comparatively, this treatment produced about 10.7% grain yield advantage over the other treatment combination that emerged along with 2146 kg ha^{-1} o 82.5% GY advantage over control (no fertilizer and lime) On the other hand, significantly ($P<0.05$) different yiel improvements resulted from OnS than OnF sites due t favors on the routine crop management practice an follow up starting from land preparation up to harvestin whereas the OnF site was treated like common farmers management practices.

Grain quality parameters like thousand seed weigh (TSW), hectoliter weight (HLW) and grain moisture (MST content were significantly ($P<0.05$) affected by applicatio of different sources of phosphorus fertilizer an experimental location variability. All of the above qualit parameters showed significantly ($P<0.05$) higher result a OnS experimental location. From different sources of F fertilizer, NPSB was found superior TSW (44.1 g). Othe parameters were not significantly ($P<0.05$) affected by F sources. Lime application and rate of P fertilizer als could not affect any of the considered grain qualit parameters significantly.

Generally, use of NPSB fertilizer at 69 kg ha^{-1} P_2O_5 rat with lime application can give maximum yield of barle under acidic soils of Wolmera. PARP at the application c 69 kg ha^{-1} P_2O_5 produced comparable GY and AGB wit lime application. These findings supplement the researc result of Shiferaw and Anteneh (2014) which have als indicated that half dose of recommended lime applicatio with balanced fertilizer significantly increased barley yield

Table 7. Interaction effects of different agronomic parameters of barley as affected by different sources of P fertilizer and lime application.

Level of significance	PH	SPL	NSK	DF	DM	AGB	GY	HLW
* ($P \le 0.05$)	L×LM		L×PS×PR×LM					
** ($P < 0.01$)			L×LM		L ×PS	L×PS	L×LM	L×LM
*** ($P \le 0.001$)		L×LM		P×L×LM				

PH- plant height, SPL- spike length, NSK- number of spikelets per spike, AGB- above ground biomass, GY- grain yield, DF- date of flowering, DM- days to mature, HLW- hectoliter weight, PS- P source, L- location, LM- lime rate, PR- phosphorus rate.

Table 8. Plant P, N and S concentration as affected by the application of lime, P sources and P rates.

Source of variation		Biomass P (%)	Grain P (%)	P Bs (kg ha^{-1})	P Gy. (kg ha^{-1})	PHI (%)	N (%)	S (%)
P sources	PARP	0.063	0.235	2.405^{B}	7.37^{B}	76.6	1.206	0.088
	MOHP	0.066	0.232	2.554^{B}	6.596^{B}	73.8	1.196	0.098
	NPSB	0.071	0.252	3.276^{A}	9.45^{A}	74.6	1.221	0.090
	NAFAKA	0.070	0.228	2.376^{B}	6.13^{B}	72.9	1.239	0.095
LSD		Ns	Ns	0.61	1.66	Ns	Ns	Ns
Fertilizer rate	PR1	0.067	0.2417	2.549	7.13	74.7	1.204	0.089
	PR2	0.068	0.2418	2.757	7.69	74.2	1.229	0.096
LSD		Ns	Ns	Ns	Ns	Ns	Ns	Ns
Lime	LM1	0.065	0.242	2.33^{B}	7.026	75.4	1.175	0.091
	LM2	0.070	0.241	2.97^{A}	7.79	73.5	1.257	0.094
LSD		Ns	Ns	0.42	Ns	Ns	Ns	Ns
Location	OnS	0.094^{A}	0.288^{A}	3.89^{A}	9.92^{A}	71.6^{A}	1.196	0.078
	OnF	0.041^{B}	0.195^{B}	1.42^{B}	4.89^{B}	77.4^{B}	1.234	0.108
LSD		0.006	0.021	0.43	1.19	3.17	Ns	Ns
Mean		0.0674	0.242	2.65	7.41	74.5	1.21	0.093
CV %		12.9	11.9	22.18	22.08	5.64	12.14	24.1

P.Bs- P uptake in plant biomass, P.Gy- P uptake in barley grain yield. Means with the same letter don't have significant difference each other, PHI- phosphorus harvest index, N%- nitrogen concentration, S%- sulfur concentration.

under acidic soil condition.

From interaction analysis result, SPL and DF of barley was significantly ($p<0.001$) affected by location and application of lime (LM) interaction (Table 7) as a result of different edaphic factors shown in Table 3. PH and NSK growth parameters were significantly ($p<0.05$) affected by (L×LM) and (L×PS×PR×LM) interaction factors respectively. On the other hand, SPL and DF was significantly ($p<0.001$) affected by location and lime application interaction effects (Table 7). Another study also showed that application of lime in different soil types and locations responded differently depending on its physicochemical properties (Kumar, 2012).

Effects on plant nutrient concentration and phosphorus uptake

Phosphorus concentration in the straw and grain of barley were non-significantly ($P<0.05$) influenced by P sources, rates and lime application (Table 8). On the other hand, P concentration was significantly different between the two experimental locations. P uptake in the straw and grain of barley was significantly affected by P

Table 10. Dominance and marginal rate of return analysis result on application of lime and different P sources of fertilizers.

Treatment			TVC (USD ha^{-1})	GFB (USD ha^{-1})	NB (USD ha^{-1})	Dominance	C	B	MRR %	B:C ratio
PS	RT	LM								
P0	PR0	LM0	0	677.49	677.49					
P4	PR1	LM1	73.51	686.45	612.94		73.51	135.44	184.25	0.122
P4	PR2	LM1	84.81	796.92	712.11	Dominated				
P4	PR1	LM2	99.74	960.59	860.85		26.23	47.92	182.70	0.172
P3	PR1	LM1	102.25	1172.56	1070.31		2.51	209.46	8337.16	0.200
P4	PR2	LM2	111.03	1001.82	890.78	Dominated				
P1	PR1	LM1	117.2	1027.37	910.17	Dominated				
P2	PR1	LM1	125.38	917.4	792.01	Dominated				
P1	PR2	LM1	127.31	992.92	865.61	Dominated				
P3	PR1	LM2	128.48	1173.84	1045.38	Dominated				
P3	PR2	LM1	142.4	1363.58	1221.19		40.15	150.88	375.81	0.205
P1	PR1	LM2	143.42	967.29	823.87	Dominated				
P2	PR2	LM1	143.43	935.44	792	Dominated				
P2	PR1	LM2	151.61	1021.53	869.91	Dominated				
P1	PR2	LM2	153.53	1128.41	974.88	Dominated				
P3	PR2	LM2	168.62	1410.88	1242.25		26.23	21.07	80.33	0.363
P2	PR2	LM2	169.66	1032.89	863.22	Dominated				

PS- P sources (P1: PARP, P2: MOHP, P3: NPSB and P4: NAFAKA), PR- P fertilizer rate (PR1: 34.5 kg ha^{-1}, PR2: 69 kg ha^{-1}), LM- lime application (LM1 without lime, LM2: with lime).

F3, PR1, LM2; and 43.9% net benefit advantage from treatment P1, PR2 and LM2.

In general, the net economic benefit result showed that the NPSB source of P fertilizer have got superior advantage over other fertilizer types followed by the PARP source of P fertilizer in combination with lime application.

Dominance analysis and marginal rate of return

The dominant analysis result showed that the net benefits of most listed treatments in the dominance table were dominated. This indicate that the net benefit decreased as the total cost that varies increased beyond undominated lime and P fertilizer treatments application in different rates. The computed %MRR result showed the highest marginal rate of return result 8337.16% was obtained from treatment combination NPSB fertilizer with 34.5 kg ha^{-1} P_2O_5 application rate on mean values of both experimental locations (Table 10). According to CIMMIT (1988) most commonly on fertilizer trials, minimum rate of return used are 100%; consequently all un-dominated set of treatment combinations except the least ones have % MRR values that were more than the minimum acceptable ones for fertilizer experiment.

From lists of un-dominated treatments, the next higher 375.8 %MRR result was found from treatment combination NPSB with application rate of 69 kg ha^{-1} P_2O_5 without lime LM1; then finally, the least MRR result was from the same treatment which differs on the application of lime with LR2. With 80% MRR, this treatment got the highest net field benefit in cash from all other treatment combinations. On the other hand, the only other P source which have un-dominated higher 184.3 and 182.7% MRR result is NAFAKA blend fertilizer without (LM1) and with (LM2) application of lime respectively, both of which has 34.5 kg ha^{-1} P_2O_5 application rate.

Conclusion

Field experiment was conducted to assess and evaluate the effects of different phosphorus sources and their application rate with and without lime on agronomic performance of food barley (*H. vulgaer* L.) at Holeta (on-station) and Rob Gebeya (on-farm), which are located in Wolmera district of "*Finfine Zuria*" special zone of Oromia region under rain fed condition during '*Meher*' season in 2017. This experiment has three factors laid out in factorial RCBD arrangement with three replications. The treatments consisted of four different P sources (granular partially acidulated rock phosphate PARP, organic hyper phosphate MOHP, blended fertilizer formula - II (NPSB) and NAFAKA plus complete blended fertilizer); two application rates of the phosphorus fertilizer (34.5 and 69 kg P_2O_5 ha^{-1}) and two lime rates (limed and without lime). A total of 16 experimental treatments were evaluated with three replications under two locations.

The preliminary soil analysis results indicated that: experimental sites had clay and clay loam textural class with 1.02 and 1.14 g/cm^3 bulk density respectively for OnS and OnF sites at surface (0-20 cm depth). The soil test result indicated that it was strongly acidic pH; medium range of total nitrogen; low in OC%, high in available K^+; very high and high concentration in Ca^{2+} and Mg^{2+}; medium rate of SO_4/S and marginal to low in its boron levels for both testing sites. The soil test results also revealed very low and low in its available phosphorus, medium and high in CEC, very high and high in percent base saturation (PBS) level respectively at on-station and on-farm experimental sites.

ANOVA result confirmed that using different source of Phosphorus fertilizer significantly ($p<0.05$) affected plant height, number of tillers per plant, date of flowering and maturity, above ground biomass, grain yield and 1000-seed weight. Application of NPSB as P source substantially improved the agronomic parameters like PH, TT, ET, DF, DM, AGB, GY and TSW by 11.9, 43.6, 50, 41.9, 7, 92.5, 88.9 and 15.2% respectively over the control treatment. As an alternative, PARP source of P fertilizer also resulted in remarkably competent biomass (58.7%) and grain yield (51.5%) improvement over the control treatment.

On the other hand, application of lime also significantly ($P<0.05$) improved spike length, number of spikelets per spike, number of total and effective tillers per plant, above ground biomass and grain yield with 3, 4.5, 21.4, 20.9, 8.6 and 6.4% improvements respectively for all experimental sites on average. Even if application rate of P_2O_5 did not significantly affect agronomic parameters, higher P fertilizer rate at 69 kg ha^{-1} P_2O_5 showed superior mean results on considered agronomic parameters, thus use of varied forms of phosphorus fertilizers from organic and inorganic blended form improved the productivity of acidic soil with lime application and can provide competent crop performance with higher grade water soluble fertilizers by promoting slow release of plant available phosphorus as it improves crops nutrient use efficiency and physical qualities of barley grain in balanced soil fertilizer management. It is mandatory to seek the alternative sources of phosphate fertilizer since the dominantly existing sources become less efficient especially on acidic soils and its natural reserves became depleted. In these regards, alternative sources with competent economic advantage and less environmental impacts should be considered as a great success for sustainable agricultural productivity to insure food security for ever increasing world population.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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PROFILE WATER CONTENT DISTRIBUTION AS AFFECTED BY MAIZE-SORGHUM INTERCROP

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ABSTRACT
Moisture supply is the main limiting factor in rain fed production in the tropics. Farming systems have evolved which attempt to maximize this limiting resource. Intercropping is a cropping system widely practiced in the Nigerian savanna that utilizes moisture to produce several crops on one piece of land. A field experiment was conducted during the wet season in 2000 at the Research Farm, Institute for Agricultural Research, Samaru, Nigeria to evaluate the effect of intercropping on the water content distribution pattern of an alfisol. The trial involved maize and sorghum varieties planted as intercrop and a grass plot laid out in randomized complete blocks in three replications. Significantly higher soil water content was found in the grass plots. Maize and sorghum plots exhibited similar soil water contents up to the 45 cm soil depth. Beyond this depth, the treatments had similar soil profile moisture content. Soil water availability investigation showed that the top 60cm of soil has about 57mm of available water. The soil has enough available water to enable successful production of both crops.

Keywords: Maize-sorghum intercrop, profile water content, water availability

INTRODUCTION

The farming systems in the Nigerian savanna can be classified as low- input and low-output type of production (Ogunwole, 2000). Intercropping is a common farming system practiced by almost all small scale farmers. Maize and sorghum intercrop is a dominant practice among farmers in Northern Nigeria (Ogunwole, 2000). Few studies have been made regarding soil water relationships in the Samaru area (Kowal, 1970, Agber, 2001, Sani, 2004). Monitoring of soil water content is important for managing water resources appropriately. Water balances in soils are influenced by conditions in the field such as the amount of vegetation on the soil surface and crop management practices. Soil water content has been investigated by a number of researchers (Kowal, 1970; Norwood, 1999; Bonfil, 1999., Yoo *et. al.*, 1995; Hendrickx *et. al.,*1990) for a variety of cropping systems. Crop yields are assumed to be limited by low soil moisture in the tropics (Agnew, 1982). However, a detailed study of the soil water dynamics may reveal that there is actually enough moisture in the soil to satisfy crop production. The capacity of the soil to absorb and retain water provides a reservoir from which plants can obtain water and grow. Soil water dynamics play an important role in determining the type of crop or cropping system practiced in an area. Knowledge of this is therefore critical to ensuring successful production systems and sustainable use of environmental resources. Different soils have different capacities for water storage. Soil water management is an important and integral part of the overall cropping system. Detailed information is therefore needed in order to develop efficient methods of soil water management that will maximize the use of this important resource.

The objective of this study was to examine the effect of intercropping on soil water content in order to develop more efficient crop production systems.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of the Institute for Agricultural Research, (IAR) farm at Samaru (11^0 11′ N, 7 ^{0}37′E and 675m above sea level), Northern Nigeria. The area lies within the Northern Guinea savannah zone of Nigeria. The length of the wet season ranges between 160 and 180 days (May to October). Mean daily air temperatures (minimum and maximum) range between 15°C and 38°C. The wind speed ranges from 77.2 km/day in October to 128 km/day in March, with a north easterly to south westerly wind direction dominating from November through April. The soil belongs to the Alfisols group (USDA System, Møberg and Esu, 1991) which has developed on deeply weathered pre-cambrian basement complex rocks but overlain by aeolian drift of varying thickness. The experiment was designed as randomised complete blocks with three replicates. It comprised three treatments: maize, sorghum and grass plots. A neutron probe, model 503 Hydroprobe (CPN Corp., Martinez, California (U.S.A) which is a nuclear moisture depth gauge was used to measure soil moisture content at depths 0 to 90 cm with 15 cm increments. The neutron probe allows small changes in *in-situ* soil water storage to be estimated.

These subsequent estimates, which are repetitive at the same place, are also not confounded with soil variability, as long as the sphere of importance (or influence) not changing much. Soil moisture content was measured after every rainfall. Volumetric water content at each depth was computed using calibration equation for the site by Agber (2002).

The soil water balance equation used is as follows.

$\Delta S = P + G + N - Et - D - Ro + Ir$

Where ΔS is the change in soil water content, P is rainfall, G is groundwater flow, N is surface inflow, Et is evapotranspiration, D is drainage and Ro is runoff and Ir is irrigation. D and Ro were assumed to be negligible.

Table1: Mean of climatic data at Samaru during the wet season, 2000

Month	Decade	Rainfall (mm)	Temperature (^0C) Maximum	Minimum	Evaporation	Mean Relative Humidity (%)
May	1	1.2	35.2	17.8	10.7	70.8
	2	11.6	36.5	19.8	8.9	69.7
	3	136.7	37.5	21.0	10.5	78.3
June	1	82.8	39.4	22.9	12.6	81.5
	2	65.4	36.3	20.5	11.2	73.5
	3	45.2	38.4	25.5	11.6	60.0
July	1	93.1	34.8	21.6	10.2	53.8
	2	62.4	36.0	25.1	7.9	73.8
	3	65.6	38.4	27.3	9.6	81.8
August	1	63.9	38.9	22.0	NA	59.9
	2	105.7	38.2	26.5	NA	66.6
	3	75.6	35.6	23.6	NA	85.5
September	1	103.8				
	2	59.3				
	3	19.0				
October	1	78.0				
	2	0.2				
	3	0.0				

NA – Data not available

Soil water content

Soil water content distribution at the initial stage of growth, is illustrated in Fig. 1(a). the results show a near uniform soil water content distribution for all treatments. This could be due to the low moisture requirement by both maize and sorghum at this stage of growth and the thin nature of the grass cover on the soil surface which may not prevent evaporation from depleting the soil moisture. Hence the moisture loss is almost the same as that of the other treatments (maize and sorghum). There is no significant difference in soil water content between the treatments.

At the mid-growth stage, (Fig 1b), the grass and sorghum treatments had significantly more soil moisture content than maize at the upper layers. However, in the lower depths (after 60cm), the soil water content values were similar, this may be due to increased clay content in the lower depths. Sorghum had significantly lower soil water content than grass. This may be due to the fact that the grass cover has become thick enough to prevent water loss through evaporation. The significant differences in soil moisture content between sorghum and maize could be due to the fact that maize requires a lot of soil moisture to satisfy its physiological needs. Sorghum on the other hand requires just a fraction of the moisture required by maize because it is still in the vegetative stage of growth which does not need the same amount of moisture like maize needs at this stage of growth.

At maturity (Fig. 1c), the soil water content distribution shows that there was a significant difference in soil water content amongst all the treatments. The grass plots had significantly higher soil water content than both maize and sorghum plots. This may be due to the fact that grass usually has short and fine roots, leading to a uniform root structure. Sorghum had significantly more soil water content than maize in the upper soil layers. Overall the treatments exhibited high soil moisture contents at this stage. With regards to the high soil water content in sorghum plots, it could be adduced to the fact that at this stage of the life cycle of sorghum, it does not require much soil moisture having passed the most critical stage of growth (heading).

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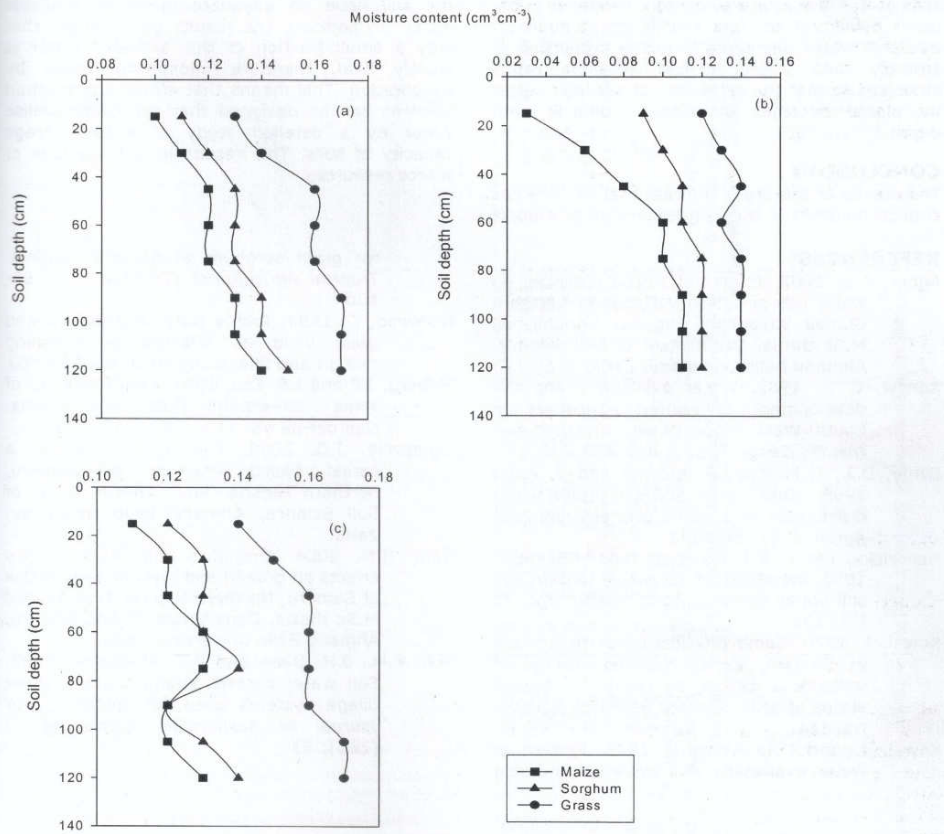

Fig.1: Trend of soil profile water content at the vegetative (a), mid-growth (b) and ripening (c) stages respectively

Water availability

The trend of soil water availability for the treatments indicated that at the surface 15cm, about 0.13cm^{3}cm^{-3} is available for plant use (Table 2). This is however subject to the force to which the water particles are held to the soil. Further investigations revealed that water is more readily available in the upper soil layers than at the lower depths. This is due to an increase in clay content as one goes deeper down the profile (Table 2). This is the situation up to about 60cm from where the layers exhibit similar soil moisture contents. Kowal (1970) studied the water availability properties of this area and reported soil available water of about 80mm in the top 60cm. In this study, there is about 57mm of available water in the top 60cm of soil (Table 2). This water is held at tensions of between 0.3 bar (Field capacity) and 15 bar (Permanent wilting point). The soil water investigations revealed that there is a lot of soil moisture held at higher tensions that is not readily available to crops (Table 2).

Kowal and Andrews (1973) reported that for the soils of this area, the clay content increases in the lower depths of the soil profile, the amount of available water decreases, and the proportion of strongly held water in the available range increases so that the extraction of available water by plants becomes increasingly difficult with depth.

CONCLUSION

The results of this study indicate that the soil has enough moisture in the available range to support successful crop production. The upper layers of the soil have an adequate range of available water. In addition, the results also indicate that only a small fraction of this available water is loosely held, therefore minimizing losses by evaporation. This means that efficient production systems can be designed that can better utilise water by a detailed study of water storage capacity of soils. This results in less wastage of scarce resources.

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4.0 CONCLUSION

Breaking a research paper into the sections Introduction, Materials, Results and Discussion (IMRAD) is a well-established approach to writing and publishing scientific research. It has become the main pattern for research articles in many disciplines. This classical structure does not fit some disciplines, but it is a useful and systematic way in which to approach your writing.

5.0 SUMMARY

At the end of the unit, we were able to understand what a journal is, the features of a journal ranging from the title down to the references and appendices, we also get see some formats of some journals.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is a Journal?
2. Discuss in sequence the features of a journal
3. List the five most popular journals in soil science. Find samples of articles in these journals online

7.0 REFERENCES/FURTHER READING

Scientific Writing for Agricultural Research Scientists: A Training Resource Manual: New Edition 2012; edited by Anthony Youdeowei; Paul Stapleton; Rodger Obubo

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