MULTIVARIATE ANALYSIS FOR A SPLIT PLOT DESIGN WITH A COVARIATE TO DETERMINE THE EFFECTS OF DIFFERENT FERTILIZERS LEVELS FOR THREE POTATO VARIETIES

BY

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DECLARATION

This dissertation is my original work and has not been presented for a degree in any other University.

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DECLARATION BY SUPERVISORS

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ABBREVIATIONS AND ACRONYMS

ANCOVA -Analysis of covariance

ANOVA -Analysis of variance

DAP -Diammonium phosphate

Df -Degree of freedom

DMC -Dry matter content

DV - Dependent variables

EDA -Exploratory Data Analysis

FAO -Food and Agriculture Organization

FYM - Farm yard manure

ha -Hectare

Ha -Alternative Hypothesis

IV -Independent variables

KARI -Kenya Agricultural Research Institute

Kg -Kilogram

LSD - Least significant difference

MOARD -Ministry of Agriculture and Rural Development

MS -Mean Square

MSE -Mean Square Error

QQ -Quantile-Quantile Plots

RCBD -Randomized Complete Block Design

SAS -Statistical Analysis System

SPSS -Statistical Package for Social Scientists

SS -Sum of Squares

ton -tonnes

UNESCO -United Nations Educational, Scientific and Cultural Organization

ACKNOWLEDGEMENT

I single out the contribution and wise counsel of my supervisors Mr. J.N.Mwangi and Prof M.M.Manene. They supported me tirelessly and gave invaluable advice. I appreciate Mr. Mwangi for his patience and facilitation in the acquisition of the data from KARI that I have used in my study. I recognize the contribution of all my lecturers while undertaking the MSc course namely:Mr Mwangi,Mr Ndiritu,Mrs Wang'ombe,Mr Obudho,Mr Omwenga,Mr Awiti,Dr Kipchirchir, Dr Owuor,Dr Oeba,Prof Weke,Prof Ottieno and Prof Manene. I appreciate the support and sacrifice shouldered by my wife, Lilian and daughters Wanjiru and Ngubia unreservedly who understood my occasional absence in family matters.

DEDICATION

I dedicate this degree to my parents Mbugua Mwega and Lucy Wanjiru for believing in me when I was young and spared no effort to see me pursue education. I pursue this course as a testimony to their belief and to inspire the young and the old to pursue further education.

ABSTRACT

Kenya's population is over forty million putting considerable pressure on production of food. This has led to continuous planting resulting to less fertile soils. The yield decreases season after season .This study seeks to find the effect of four different types of manure (poultry,goat,cow) and DAP(Di-Ammonium Phosphate) on three different varieties of potatoes(Annet,Dutch Robyn and Kenya Baraka).Each of the different type of manure was applied to each variety at three different levels. This experiment was carried out at Tigoni, Kenya measuring the difference in seed yield and dry matter content (DMC).The overall objective is to determine the most productive variety in a given rainy season and at what manure/fertilizer level. Soil nutrient deficit can be met from two sources: farmyard manure and commercial fertilizers. Potato varieties were planted for two seasons. The experimental design was such that treatments were laid out in a randomized complete block design replicated three times and consisted of poultrymanure;(2.5,5.0,10.0tons/ha),goatmanure;(5,10.0,15.0tons/ha),cowmanure;(15.0, 20.0,25.0) and DAP (18:46:0) at (.24, .28,.32tons/ha).Split-plot designs are needed when the levels of some treatment factors are more difficult to change during the experiment than those of others. Analysis is done to determine superior treatments in each of the rainy seasons (short & long) for each variety. The optimal level was identified of the seed yield and DMC.The results show that DAP fertilizer had optimal level for the yields during short rains, long rains and combined seasons at .28tons/ha.The DMC had optimal level during short rains using goat manure at 10tons/ha, while during long rains DAP had optimal level at.28 tons/ha.The combined seasons had optimal level using goat and DAP at 10tons/ha and .28 tons/ha respectively

Key words: DMC (Dry matter content), Diammonium phosphate (DAP), Annet, Dutch Robyn, Kenya Baraka.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND INFORMATION

Potato originated in the highlands of South America, where it has been consumed for more than 800 years. Spanish explorers brought the plant to Europe in the late 16th century as a botanical curiosity. By the 19th century it had spread throughout the continent, providing cheap and abundant food. Potato arrived in Africa around the turn of the 20th century. British farmers introduced it to East Africa in the 1880s. Potato has grown in importance - both as a staple food and as a source of farmer incomes in medium to high altitudes in Kenya over the past 30 years.

Potato is relished by the rural people who grow them and also by higher-income urban dwellers. In Kenya it is considered a high quality and prestigious food item. The national average potato yields for Kenya has been reported at 7.7 tons per hectare, but this figure has fluctuated considerably over recent years, from over 9.5 ton/ha to around 7.5 ton/ha (FAO, 2008).

1.1.1 RAINFALL CONDITIONS

Potato requires well-distributed rainfall of 500 to 750 mm in a growing period of 3 to 4.5 months. Potatoes perform well in cool climates with night temperatures below 20°C. Optimum day temperatures are within the range of 20 to 25°C. Short day lengths (12 to 13 hours) lead to early maturity. In the short day length conditions of the tropics and subtropics, maximum yields can usually be obtained in cool highland areas and in cooler seasons. Cultivation is concentrated in highland areas from 1200 to 3000 m above sea level. In regions with a critical dry season, planting early in the rainy season is best. If the rainy season is long and excessive, time of planting is usually towards the end of the rainy season. Potato is tolerant to a rather wide variety of soils, except heavy, waterlogged clays. Good drainage is of great importance. Impermeable layers in the soil limit rooting depth and the amount of available water, and so greatly reduce yields. Deep soils with good water retention and aeration give best growth and yields. The most suitable soil pH is between 4.8 and 6. At higher pH, tubers are liable to suffer from scab disease.

1.1.2 Planting

In regions with a critical dry season, planting early in the rainy season is best. If the rainy season is long and excessive, time of planting is usually towards the end of the rainy season. Potato subjected to heavy rainfall during growth or harvest is prone to diseases. Tubers planted to produce potatoes for consumption should generally be planted in rows 75-100 cm apart with a spacing of 30 to 40 cm within the row (25,000 to 44,000 plants per ha). The closer spacing should be used in fertile soils and good rainfall areas to avoid the production of very large tubers. Seed potatoes are planted at a spacing of 15 to 20 cm within the row (about 80,000 plants per ha). Potatoes are planted at a depth of 5 to 15 cm (measured from the top of the tuber). Planting depth is greater under warm, dry conditions than under cool, wet conditions. Shallow plantings should be avoided, because the lower nodes of the stem must remain covered to encourage tuberisation (tuber initiation) and to avoid greening of tubers and tuber moth damage. Earthing up or hilling is carried out to control weeds and to avoid greening of the tubers. Potatoes are normally planted by hand in developing countries, but mechanical planters are available. Plough-under or incorporate available organic manures in the soil before planting to enhance the water-holding capacity and texture of the soil as well as to provide enough nutrients for a healthy crop.

A high yielding potato crop under conventional farming removes 95 to 140 kg N (nitrogen)/ha, 35 kg P (phosphorus)/ha, 125 to 170 kg K (potassium)/ha and has relatively high needs for Mg (magnesium) and Mn (manganese). Potatoes respond well to large amounts of compost or well-rotted animal manures. Fertilizers recommendations based on soil analysis offer the very best chance of getting the right amount of fertilizer without over or under fertilizing.

Table 1: Characteristics of the three varieties covered in this study:

Variety	Yield	Storage	Drought resistance	Late blight	Viruses	Maturity	Eco-zone
Kenya Baraka	High	Good	Some resistance	Some resistance	Some resistance	Medium	Medium High
Annet	High	Good	Some resistance	Some resistance	Some resistance	Early	Medium High Low
Dutch Robjn	High	Very good	Some resistance	Susceptible	Some resistance	Medium	High Medium

1.1.3 Husbandry

Adequate control of weeds is required to ensure high yields. In the tropics, manual weeding is generally practiced in small-scale production, but herbicides are sometimes used in large-scale production. Potato responds well to high soil fertility. Manure or compost is needed if the land has been continuously cropped. Well-decomposed animal manure or compost is recommended.

1.1.4 Harvesting

Time of harvesting of potato varies with cultivar, cultural practices, climate and price. Tubers harvested while still immature tend to have low dry matter content and to suffer more skin damage, resulting in easier infection by fungal and bacterial pathogens.

1.1.5 Yield

In 1996, the average yield of storage potato tubers throughout the world was about 16 tonnes per hectare (t/ha). Average yields (t/ha) for different continents in 1996 were: Asia (14.5), Africa (11.3), North America (39.1), South America (12.6), Europe (16.2) and Oceania (28.8). In many tropical and subtropical regions potential yields are much higher than actual yields due to constraints (environmental, seasonal, propagation, crop protection, economic and social) that prevent the full expression of this potential, but individual farmers in Kenya have reported yields up to 35 t/ha. Potatoes are widely used in Kenya as part of main stable food. This is attributed to being grown in diverse part of the country during short and long rain seasons. The popularity of potatoes is attributable to their being generally adaptable, fast growing with a wide range of utility from roasted potatoes, fried (chips) and traditional foods (mukimo,irio). Potato is an important horticultural crop worldwide used as human food as well as animal feed. However, in Kenya, potato ranks the highest horticultural crop in terms of hectarage accounting for 108,516 ha, yielding 670,303 metric tonnes (MOA and RD, Annual report, 2000). The tubers are boiled or steamed, baked, roasted, or used as chips. Besides insect pests and diseases, low soil fertility is a major constraint to potato production in most parts of the country. In Kenya the main potato producing areas have, an annual rainfall of more than 1000mm and altitudes above 1500m. However, with increasing land pressure in these areas, ways of increasing potato production are being sought. In Kenya, potato ranks second after maize with approximately 25 000 to 30 000 hectares being grown annually, granting employment to more than 2.5 million people across the entire production and marketing chain. The challenge of potato production lies in farmers getting quality seeds of superior varieties. This is hampered by low quantity of certified seed tubers produced and available for sale. Many private breeders/seed producers shy away from seed potato tuber reproduction, opting to breed seeds such as maize. Most of the potatoes producers are small scale that has less than an acre to plant, inadequate finances to buy fertilizers or venture into alternative income generation and with erratic rain patterns. The alternative is to manage the soils for better production. The overall objective is to identify technologies that optimize production and the best season. The treatment and plot layout remain constant during both long and short rainy seasons.

1.2 LITERATURE REVIEW

Potato is an important horticultural crop worldwide used as human food as well as animal feed. In Kenya, potato ranks the highest horticultural crop in terms of hectarage accounting for 108,516 ha, yielding 670,303 t (MOA and RD, 2000). The tubers are boiled or steamed, baked, roasted, or used as chips. Low soil fertility is a major constraint to potato production in most parts of Kenya besides insect pests and diseases. Potato yields about 8 ton ha-1 (MOA and RD., 2000), which is much less than 30 - 40 MT ha-1 realized in Kenya with the application of fertilizer N-P-K (60-60-40) (Nandasaba *et al.*, 1999; Martinez and Pell, 2000). The use of FYM on low value crops, such as maize, is not as economical as when used on high value crops, such as, potatoes. Therefore, there is need to encourage the use of organic manure on high value crops as opposed to the low value ones. The major constraint to potato production in the cool highlands of Kenya is the rapid decline in soil fertility occasioned by continuous cultivation without adequate replenishment of mined nutrients (Kiiya etal. 2006, Nga'ng'a etal; 2008). Plots occurring close together within an agricultural field area are more similar than plots occurring far away from each other according to Gupta *etal* (2004). It is logical that yield from a plot is closely related to the yields from its immediate neighbors due to inherent positive correlation between the fertility of neighboring plots. The environmental variations can adversely influence the results of a statistical analysis and interfere with its interpretation according to Loughin (2007).Treatment regimes are assigned to experimental units at the start of the study in a randomized complete block design and total yield and DMC is measured at the end.Validty is achieved through randomization, in allocating treatments to experimental units. Randomization makes it possible to draw rigorous inductive inferences by use of statistical theories. Precision is achieved through replication (i.e. more than one experimental unit per treatment) and use of appropriate experimental design. To gain efficiency then precision was increased without increasing the size of the experiment, done by selecting on experimental design that results in a smaller value of experimental error variance.

The use of FYM on low value crops, such as maize, is not as economical as when used on high value crops, such as, potatoes. Therefore, there is need to encourage the use of organic manure on high value crops as opposed to the low value ones. The main objective of the study was to assess the potential for producing good quality potato with high yields through use of farmyard manure with reduced quantities Potato is an important food and cash crop that plays a major role in food security. The crop is rated second to maize in terms of utilization in Kenya. Production in the country is confined to the highlands, where the crop performs better in terms of yield in comparison to other staple foods including maize. French fries and potato crisps are the most consumed industrially processed potato products in Kenya, especially in the major urban centers. Fisher (1996) has defined a valid estimate of error variance or mean square as one which contains all sources of variation affecting treatment effects except those due to the treatments themselves. This means that the estimated variance should be among experimental units treated alike and not necessary among observations. There is a direct relationship between complete confounding of effects from a factorial treatments design and a split plot design. The complete confounded effects take on the role of whole plot treatments, and the combination making up the levels of these effects are the split plot treatments according to Federer, W.T &King F (2000).

The knowledge of variation can separate the varietal differences from other source of variation. ANOVA being a technique of knowing varietal differences due to known and unknown variation among the treatments. According to Mulla etal (1990) in ANOVA, the method of application of fertilizers and rate of fertilizers have profound significant on Potato experiment. In contrast to results of ANOVA, the results of ANCOVA found that only rate of fertilizer application is statistically significant after adjustment for effect of soil pH, and the interaction between pH and method is significant in covariance analysis. Alexandra K et al., (2005) found that an ANOVA-based conclusion was that the control (no manure) treatment was not different from the surface applied manure treatment.

1.3 PROBLEM STATEMENT

Feeding the people continues to be a major challenge. The situation is made worse by the infertility of the land due to continuous use. Inappropriate soil management and soil degradation ought to be arrested for maximum productivity. Potatoes are major part of Kenyan diet on daily basis. There are three varieties under investigation, determining the one with highest output.

There are two rainy seasons (long & short).Long rain season stretches from March to May whereas short rain seasons kicks off from October to December. There is need to find which season results in maximum yield. The potatoes are subjected to four different manures (poultry, goat, cow and DAP fertilizer), each at different levels. The question that arises is which is the best variety? At what season do we have optimal yield as well as the type and level of manure to use?

1.4 Overall objectives

To determine the maximum yield of potato seed and DMC given two different rainy seasons and variation in types of manure.

1.5 Specific objectives

1. To assess the productivity of potatoes
2. To determine the best (most productive) rainy season
3. To determine the best variety in each season given each type of manure/fertilizer
4. To determine the optimal rates for manure/fertilizer
5. To fit several models to the data and identify the best among them
6. To determine superior treatments over time

1.6 Hypothesis

The null hypothesis to be tested is Ho: $\mu_1 = \mu_2 = . . . , = \mu_k$ where μ_k is the mean yield of the k_{th} treatment. In other words, the null hypothesis is that all *k* treatment has the same mean yield. The alternative hypothesis (Ha) is that at least one of the treatments has a mean yield different from others.

1.7 SIGNIFICANCE OF THE STUDY

Efforts to increase food production have been key the function in agricultural researches throughout the world. Such efforts in Kenya are spearheaded by Kenya Agricultural Research Institute-KARI. The institute provides resources to investigate the best variety and best manure/fertilizer combination in all seasons. The experimental trials at KARI provide a unique resource to investigate the influence of organic and inorganic manure use.

1.8 METHODOLOGY

1.8.1 STUDY AREA

An all season trial was done by KARI at Tigoni, Kenya testing the difference in seed yield and also the DMC for three potato varieties. Tigoni is about 25km,north-west of Nairobi at an altitude of 2131m above sea level, longitude (36°40'E)and latitude(1°8' S). The soils are well drained, very deep and classified as humic nitisol (UNESCO, 1974).

1.8.2 EXPERIMENTAL DESIGN

The trial is a split-plot design with 3*4*3=36 treatment combinations randomly assigned

This experiment compared the yield of three varieties of potatoes (***factor A with a=3 levels***) and three different levels of manure (***factor B with b=3 levels***).There is four types of manure (**factor C with c=4 levels**).Steps followed is:

1. To divide each block into three equal sized plots (***whole plots***), and each plot is assigned a variety of potato according to a randomized block design.

2. Each plot is divided into four smaller plots that were assigned the four different types of manure randomly

3. The smaller plots are divided into 3 plots (***split-plots***) and the three levels of manure are randomly assigned. A model for such a split-plot design is the following: h=1, 2... s, i=1, 2... a, j=1, 2, ..., b. Note the nested blocking structure: whole plots are nested within the blocks, and split-plots are nested within the whole plots. This design applies to the other three types of manure. The four types of manure are randomly assigned. Two kinds of errors: representing the random effects of the whole plots, and representing the random effects of split plots and random noises.

1.8.3 PLOT SIZE

The plot size used was 80000 plants per hectare. The plot size was maintained in both seasons and for all varieties, different manure/fertilizer and different levels. Carry-over of treatment effects was controlled between neighboring plots by leaving two rows unplanted.

1.8.4 TEST CROP

Three varieties of potatoes were planted. These are Annet, Dutch Robyn, and Kenya Baraka

1.8.5 TREATMENTS

Below are detailed 36 treatment combinations:

1. V1F1L1, V1F2L1, V1F3L1, V1F4L1

2. V1F1L2, V1F2L2, V1F3L3 , V1F4L2

3. V1F1L3, V1F2L3, V1F3L3, V1F4L3

4. V2F1L1, V2F2L1, V2F3L1, V2F4L1

5. V2F1L2, V2F2L2, V2F3L2, V2F4L2

6. V2F1L3, V2F2L3, V2F3L3, V2F4L3

7. V3F1L1, V3F2L1, V3F3L1, V3F4L1

8. V3F1L2, V3F2L2, V3F3L2, V3F4L2

9. V3F1L3, V3F2L3, V3F3L3, V3F4L3

Where:

V -Potato varieties at 3 levels; V1-Annet, V2-Dutch Robyn and V3-Kenya Baraka

F -Fertilizer type at 4 levels; F1-Poultry manure, F2-Goat manure, F3-Cow manure and F4-DAP

L-Fertilizer levels at 3 rates; L1, L2, and L3

The fertilizer application rates vary from one manure to another as follows: poultry at 2.5, 5.0&10.0; goat at5.0, 10.0 &15; cow at15, 20 &25 and DAP at.24, .28 and.32. In each case it is tons per hectare.

1.8.6 DATA COLLECTION

The data on the potato seed yield and DMC was recorded on data recording sheets. The recording was done season wise i.e, long season and short season separately. In both cases the recording was done column wise. This raw data was then keyed in the MS Excel spreadsheet (shown in appendix) and verified against the original data sheets. Blocks variety, fertilizer type and plant count were entered for analysis after being coded. The fertilizer rates were expressed in tones per hectare. The yield data and DMC was expressed in tonnes per hectare.

1.8.7 DATA ANALYSIS

Data analysis was done using Microsoft Office Excel 2007, SAS 9.1.3 and SPSS 16.0 computer applications.

1.8.8 ASSUMPTIONS

Each of the 'n' (n=3) varieties are normally distributed with means, $\mu_1 = \mu_2 \cdots = \mu_n$ and variances $\sigma_1^2 = \sigma_2^2 = \cdots = \sigma_n^2$

CHAPTER 2

EXPLANATORY DATA ANALYSIS (EDA)

2.1 INTRODUCTION

EDA confirms whether the data conforms to the underlying assumptions of a linear model befitting a linear model.EDA is carried out to the study for each season i.e. short rain season, long rain season and combined seasons. The graphical techniques are employed with limited quantitative variables. The techniques used are histograms, box plots and Q-Q plot. These open up the data for precise trends, detecting outliers, anomalies, maximizing into the dataset, revealing possible model to be fitted.

(i)HISTOGRAMS-Shows distribution and check normality. Data is normally distributed if it has bell shape. Normal curves fits in histogram.

(ii)QQ PLOT-If distribution is normal, the plot would have observations distributed closely around the straight line.

(iii)BOX PLOT-They show the outliers either on the lower and/or upper end of the box. The measures of central tendency are deduced.

SHORT RAINS SEASON

DRY MATTER CONTENT (DMC)

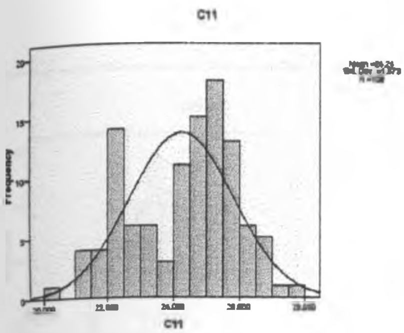


Figure 1 below shows Histogram on the C11-Dry matter content expressed as percentage indicates that the data imitates normal distribution because it has almost a bell-shaped appearance fit. The normal curve on the histogram also almost fits well on the histogram

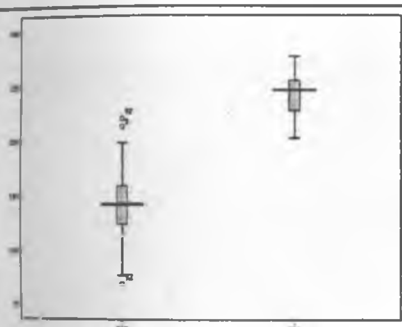


Figure 2 showing box plots of total yield (C10) and Dry matter content (DMC-C11)

The total yield, C10 shows it is normal distribution and there are significant outliers; one case beyond the lower line of the box plot and two others above the upper line. The mean, median and mode are at the same point.

The dry matter content (DMC), C11 box plot shows distribution that is not normal, though without any outliers. The mean, median and mode are at different points in the distribution.

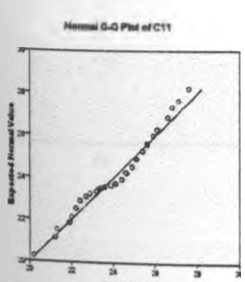


Figure3 Normal Q-Q Plot of C11

The DMC variable does not match the normal distribution since the points do not cluster around a straight line. Most of the points are not on the straight line or close to it. The figure shows deviations from normality on both ends.

(II)YIELDS

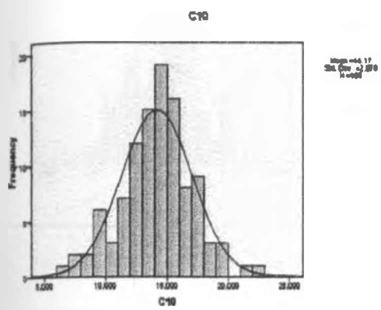


Figure4 shows histogram on the C10-total Yield expressed as percentage during the short rains. The histogram indicates the data is normally distributed because it has bell-shaped appearance. The normal curve fits well on the histogram.

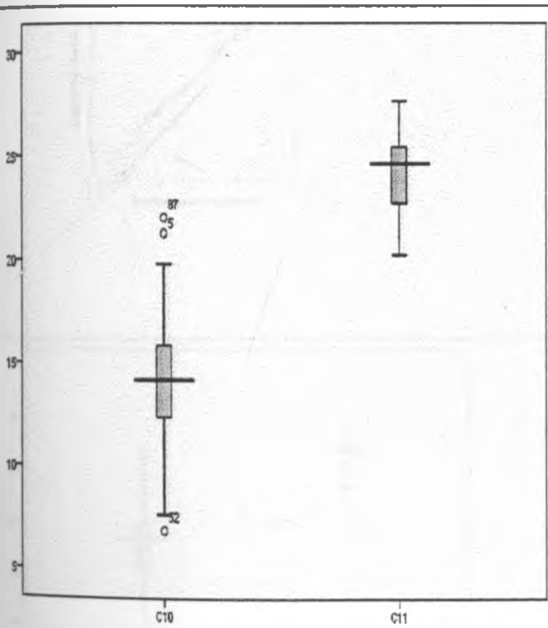


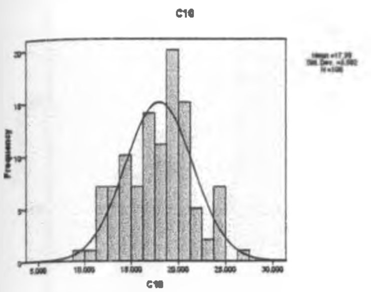
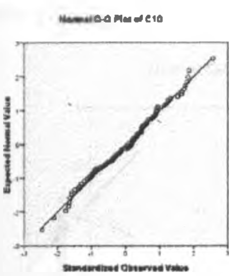
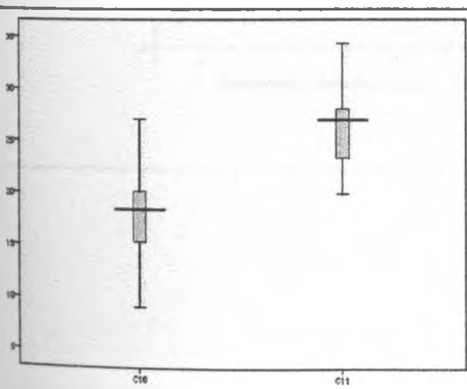
Figure 5 showing box plots of total yield (C10) and Dry matter content (DMC-C11)

The total yield, C10 shows it is normal distribution and there are significant outliers; one case beyond the lower line of the box plot and two others above the upper line. The mean, median and mode are at the same point.

The dry matter content (DMC), C11 box plot shows distribution that is not normal, though without any outliers. The mean, median and mode are at different points in the distribution.

LONG RAINS SEASONS

(i)YIELDS

	Figure 6.The data is not normally distributed Normal curves do not fit on the histogram. A big part of the histogram is above the curve.
	Figures 7.Observations are distributed closely around the straight line, though there are outliers both at the lower and upper end.
	Figure 8.In both cases there are no outliers. In C10-total yield the mean, median and mode are almost at the same point but not quite, imitating a normal curve. In the DMC, the measures of central tendencies are in different places, therefore distribution is not normal.

(ii)DMC

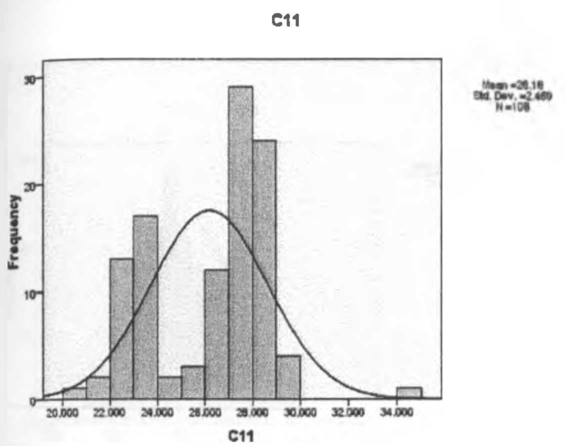


Figure9.The data is not normally distributed. It's not bell shaped. The curve does not fit on the histogram

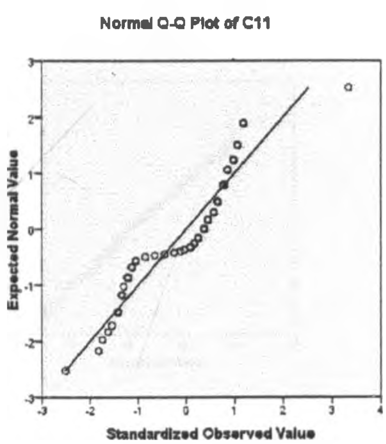


Figure10.The distribution is not normal; points are not on a straight line.

COMBINED SEASON

(i)YIELD

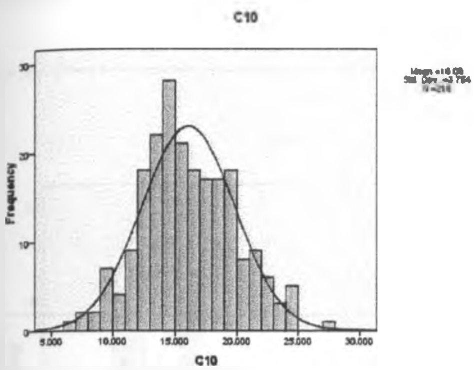


Figure11

The distribution shows an almost bell shaped appearance indicating normality with some outliers. Mean and median are not in the same position.

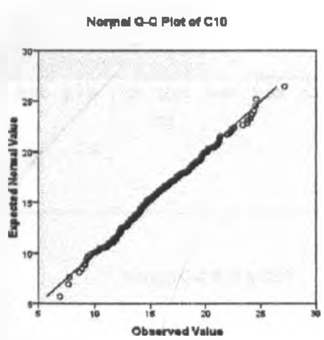


Figure12

The distribution of variables indicates a normal distribution with one outlier at the upper part and three outliers on the lower part.

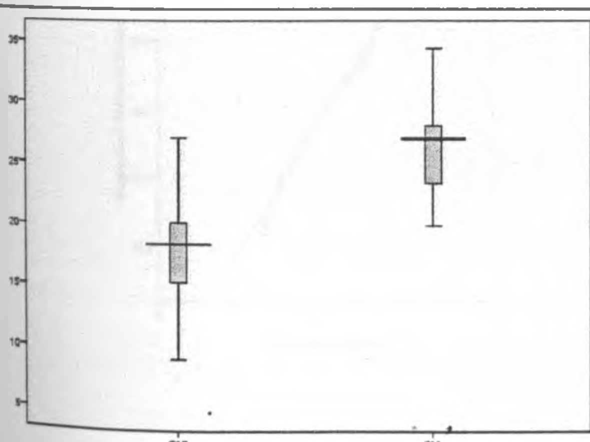
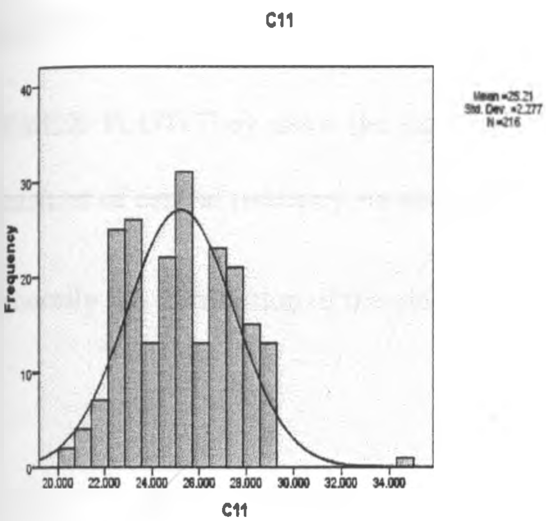
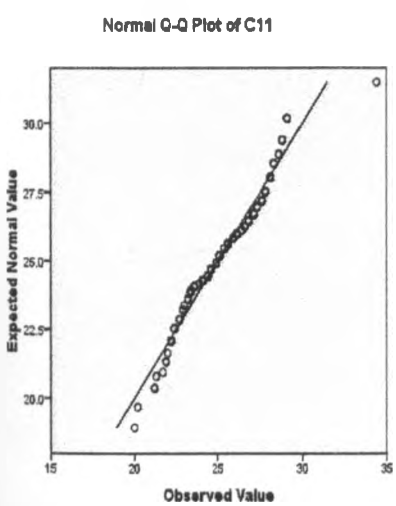


Figure13

The yield (c10) and DMC (c11) outputs do not show any outliers. The yield indicates normality since mean and median are almost at the same point but c11 fails normality test since mean and median are not at the same point.

	(ii)DMC

(ii)DMC

	Figure14. A significant part of histogram fails normality, since it is not bell shaped and the curve does not fits over the histogram.
	Figure15. The middle part indicates normal distribution; however, the lower and upper part has outliers. This does not indicates normal distribution

2.2 CONCLUSION

(i)HISTOGRAMS-Shows distribution and check normality. Data is normally distributed if it has bell shape. Normal curves fits in histogram.

(ii)QQ PLOT-If distribution is normal, the plot would have observations distributed closely around the straight line.

(iii)BOX PLOT-They show the outliers either on the lower and/or upper end of the box. The measures of central tendency are deduced.

Generally the distribution of the yield and DMC is normal.

CHAPTER 3

ANALYSIS OF VARIANCE FOR A SPLIT PLOT DESIGN WITH A COVARIATE

3.1 INTRODUCTION

Analysis of variance (ANOVA) is essentially a procedure for testing the difference among different treatments of data for homogeneity. The essence of ANOVA is that the total amount of variation in a set of data is split into two components, that amount which can be attributed to chance and that amount which can be attributed to specified causes. The basic principle of ANOVA is to test for the differences among the means of the populations by examining the amount of variation within each of these samples, relative to amount of variation between the samples. Consider the hypothesis testing for univariate case where we will only deal with a single factor design: that is, a situation in which there is no factorial structure imposed on the grouping of treatments.

3.2 ANOVA PURPOSE

In Analysis of Variance (ANOVA) the purpose is to compare the means of k treatments (k>2) on some dependent measure.

3.3ASSUMPTIONS OF ANOVA MODEL

i) The effect of ith treatment remains same irrespective of the plot.

ii) The effect of jth block/ replication remains same irrespective of the treatment.

iii) These effects are independent and additive.

iv) Errors are independently and normally distributed with mean zero and common variance.

3.4 ANALYSIS OF COVARIANCE (ANCOVA)

In an experiment, the variable under investigation P is affected by another variable, R.To improves the precision of treatments comparison, and analysis of covariance is used. This involves adjusting the observed responses for the linear effect of another factor. There are three main applications of covariance analysis according to Rajender Parsad and Gupta V.K (2008), namely:

(i)**Error control**-appropriate use of experimental and/or sampling designs is aimed at controlling error. Proper blocking can reduce experimental error by maximizing the differences between blocks resulting to minimization of differences within blocks. By measuring covariates X_1 (additional variables) known to be linearly related to the primary variable P,the sources of variation associated with covariates can be eliminated from experimental error. Examples of where covariance analysis will be experienced are soil heterogeneity, irregularities in stand counts, non-uniformity in environmental stress etc

(ii)**Helping in interpretation of research** results-by examining the primary character and other character whose interrelation is known then the biological processes governing the treatments effects on the primary character is characterized. The treatments effect could influence both the yield of the crop and the weed population, or insect intensity, as a covariate can be used to distinguish the yield differences caused directly y fertilizer treatments ,and those caused indirectly by changes in weed population or insect intensity which are also caused by fertilizer treatments. Covariance determines whether the yield differences between treatments, after adjusting for the effect of weeds or insects, remain significant. If the adjustment for the effect of weeds or insect result in a significant reduction in the differences between treatments, then the effect of fertilizer on the yield of the crop is due largely to its effects on weeds. In error control, the covariate should not be influenced by the treatments, while in the interpretation of results the covariate should be closely associated with the treatments effects

(iii)**Estimations of missing data**-applicable to any number of missing values. One covariate is assigned to each missing value, (Gomez and Gomez, 1984). Extraneous variables sometimes influence the characters under study resulting in misleading interpretation. On the premise that the various biophysical features of an experimental plots do not behave independently but are often functionally related to each other, the analysis of covariance simultaneously examines the variances and covariance among selected variables such that each treatment effect on the character of primary interests more accurately characterized than by use of analysis of covariance only, and it requires measurement of the character of primary interest plus measurement of one or more variables known as covariates. It also requires that the functional relationship of the covariates with the character of primary interest is known before hand. The seed yield of all the varieties, with replicated data was found to be influenced by yield biometrical characters.

3.5 SPLIT-PLOT DESIGN

It involves randomly assigning the levels of one factor (or a combination of factors) to large plots and randomly assigning the levels of another factor (or a combination of factors) to small sub-plots within the large plots. This design is used when:

(i) when one of the factors cannot be conveniently be applied to individual small experimental units

(ii) when one or more factors are included to merely increase the scope of the experiment and where high precision on the main effects of this factor is not required.

3.6 STATISTICAL MODEL

$$Y_{ijklm}=\mu+P_i+B_j+F_k+R(F)_{lk}+(B*F)_{jk}+V_m+(F*V)_{km}+\varepsilon_{ijklm}$$

Where: μ=overall mean yield (constant)

P_i=the covariate

B_j= the block effect of

F_k=the fertilizer type effect

$(B*F)_{jk}$ =error (a)

$R(F)_{lk}$= Rate of fertilizer effect within the fertilizer type

V_m=the variety effect

$(F*V)_{km}$=Interaction effect of fertilizer and variety

ε_{ijklm}=the error term (b)

3.7 COVARIATE

Any of two or more random variables exhibiting correlated variation. It is used if experimental units differ because of the influence of continuous, regression variable; e.g. size of the potato plants (p) is measured in this experiment. It is a secondary variable that can affect the relationship between the dependent variable and other independent variables of primary interest

3.8 RESULTS

ANOVA/LSD

COMBINE SEASONS

YIELD

Table 2: Analysis of Variance/lsd of the yield

Source	DF	SUM OF SQUARES	Mean Square	F Value	Pr > F
P	8	82.1122753	10.2640344	0.96	0.4672
B	2	48.2086033	24.1043017	2.26	0.1073
F	3	458.5834511	152.8611504	14.33	<.0001
R (F)	8	76.3146761	9.5393345	0.89	0.5225
B*F	6	50.1004120	8.3500687	0.78	0.5845
V	2	298.3347013	149.1673507	13.98	<.0001
V*F	6	129.7566531	21.6261088	2.03	0.0642

F-test is done on blocks, fertilizer and fertilizer rates. The $F_{calculated}$, Fc is compared with $F_{tabulated}F_t$ so as to reject the hypothesis or fail to reject.

Blocks: Ft.05 (2, 6) =5.14

Fc=Bss/B*Fss=48.2086033/50.1004120=.9622

Fertilizers: Ft.05 (3, 6) =4.76

Fc=Fss/B*Fss=458.5834511/50.1004120=9.1533

Fertilizer rates: Ft.05 (8, 6) =4.15

Fc=R (F)ss/B*Fss=76.3146761/50.1004120=1.5232

Remarks: For the yield when Fc<Ft we fail to reject Ho: μ1=μ2=........=μn

Hence the means are not statistically different from one another for the blocks and fertilizer rates but significant for fertilizer type.

DMC

Table 3: Analysis of Variance/lsd of the DMC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
P	8	110.2132729	13.7766591	12.23	<.0001
B	2	13.3051323	6.6525661	5.91	0.0033
F	3	3.7755832	1.2585277	1.12	0.3434
R(F)	8	7.5174118	0.9396765	0.83	0.5735
B*F	6	3.0221550	0.5036925	0.45	0.8463
V	2	504.6931564	252.3465782	224.05	<.0001
V*F	6	5.7819660	0.9636610	0.86	0 .5288

F-test is done on blocks, fertilizer and fertilizer rates. The $F_{calculated,}$ Fc is compared with $F_{tabulated}F_t$ so as to reject the hypothesis or fail to reject.

Blocks: Ft.05 (2, 6) =5.14

Fc=Bss/B*Fss=13.3051/3.0221=4.4025

Fertilizers: Ft.05 (3, 6) =4.76

Fc=Fss/B*Fss=3.7756/3.0222=1.2493

Fertilizer rates: Ft.05 (8, 6) =4.15

Fc=R (F)ss/B*Fss=7.5174/3.0222=2.4874

Remarks: For the yield when Fc<Ft we fail to reject Ho: $\mu 1=\mu 2=\ldots\ldots=\mu n$

Hence the means are not statistically different from one another for the blocks and fertilizer rates but significant for fertilizer type.

t Tests (LSD) for Yield

Least Significant Difference 1.2403

Means with the same letter are not significantly different at alpha level of 0.05.

t Grouping	Mean	N	F
A	17.4301	54	1
A			
A	16.6657	54	4
A			
A	16.4443	54	3
B	13.6826	54	2

t Tests (LSD) for DMC

Least Significant Difference 0.403

Means with the same letter are not significantly different at alpha level of .05

t Grouping		Mean	N	F
	A	25.3907	54	2
	A			
B	A	25.2352	54	3
B	A			
B	A	25.0315	54	1
B				
B		24.9852	54	4

t Tests (LSD) for Yield

Least Significant Difference 1.0741

Means with the same letter are not significantly different at alpha level of .05.

t Grouping	Mean	N	V
A	17.6066	72	1
B	15.3499	72	2
B			
B	15.2104	72	3

t Tests (LSD) for DMC

Least Significant Difference 0.349

Means with the same letter are not significantly different at alpha level of 0.05.

t Grouping	Mean	N	V
A	26.7681	72	2
B	26.0583	72	3
C	22.6556	72	1

Table 4: Level of Level of variety and fertilizer for yield and DMC

Level of	Level of	-----------Yield-----------		------------DMC------------	
V	F	Mean	Std Dev	Mean	Std Dev
1	1	18.6280000	3.55932193	22.5666667	0.59803600
1	2	14.9127778	4.50812835	22.9555556	0.66174655
1	3	17.0983333	4.26115353	22.6444444	0.97571827
1	4	19.7872222	2.78166012	22.4555556	0.90762925
2	1	17.6463889	4.02831333	26.5055556	1.57796303
2	2	12.8127778	2.94657639	27.1444444	1.44149523
2	3	15.9622222	2.80574527	26.9833333	1.65146993

2	4	14.9783333	2.28950932	26.4388889	1.41593407
3	1	16.0158333	3.04839218	26.0222222	1.34363666
3	2	13.3222222	3.22003024	26.0722222	1.48870475
3	3	16.2722222	2.65392175	26.0777778	1.50745424
3	4	15.2314444	2.55983729	26.0611111	1.05503771

Table 5: Level of Level of Blocks and Fertilizer for Yield and DMC

Level of	Level of	-----------Yield-----------		------------DMC------------	
B	F	Mean	Std Dev	Mean	Std Dev
1	1	18.5172222	3.14135144	24.8111111	2.04849698
1	2	13.7641667	3.21241995	25.3111111	2.23419650
1	3	16.1219444	2.98921254	24.9777778	2.61096231
1	4	16.7125556	3.16114088	24.6222222	2.30690920
2	1	17.7475000	4.53462893	25.0833333	2.12775773
2	2	14.9922222	3.10803807	25.6444444	2.25080959
2	3	16.9483333	2.94376160	25.4611111	2.12855623
2	4	16.8425000	3.96888273	25.1277778	2.04387336
3	1	16.0255000	2.82799624	25.2000000	2.37015760
3	2	12.2913889	4.25008090	25.2166667	2.14345790
3	3	16.2625000	3.97342949	25.2666667	2.36070777
3	4	16.4419444	3.03460587	25.2055556	2.11395148

Table 6: Level of Level of fertilizer and rates of fertilizers for Yield and DMC

Level of R	Level of F	Yield Mean	Yield Std Dev	DMC Mean	DMC Std Dev
2.5	1	16.5836111	3.20780656	25.2777778	2.28770513
5	1	17.3225000	4.55666230	25.0166667	2.26306663
10	1	18.3841111	3.01457588	24.8000000	1.98731270
5	2	13.2225000	3.32010819	25.4666667	2.17715411
10	2	13.1958333	3.78773417	25.5222222	2.08172879
15	2	14.6294444	3.88854346	25.1833333	2.36972324
15	3	16.3772222	2.96855046	25.1666667	2.66987552
20	3	15.8747222	3.01896577	25.0388889	2.30807760
25	3	17.0808333	3.88581517	25.5000000	2.11437656
0.24	4	16.0470000	3.16702611	24.9222222	2.06698290
0.28	4	17.0766667	3.24001089	24.9111111	2.40217766
0.32	4	16.8733333	3.72620450	25.1222222	2.02674922

LONG RAINS SEASONS

Dependent Variable: Yield

Table 7: Analysis of Variance/lsd of the yield

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
P	8	73.2825694	9.1603212	1.26	0.2756

B	2	20.4097940	10.2048970	1.41	0.2511
F	3	200.0033513	66.6677838	9.20	<.0001
R (F)	8	91.7178269	11.4647284	1.58	0.1452
B*F	6	46.8012552	7.8002092	1.08	0.3845
V	2	157.6143278	78.8071639	10.88	<.0001
V*F	6	61.7868607	10.2978101	1.42	0.2182

F-test is done on blocks, fertilizer and fertilizer rates. The $F_{calculated,}$ Fc is compared with $F_{tabulated}F_t$ so as to reject the hypothesis or fail to reject.

Blocks: Ft.05 (2, 6) =5.14

Fc=Bss/B*Fss=20.4098/46.8013=.4361

Fertilizers: Ft.05 (3, 6) =4.76

Fc=Fss/B*Fss=200.0034/46.8013=4.2735

Fertilizer rates: Ft.05 (8, 6) =4.15

Fc=R (F)ss/B*Fss=91.7178/46.8013=1.9597

Remarks: For the yield when Fc<Ft we fail to reject Ho: $\mu 1=\mu 2=\ldots\ldots=\mu n$

Hence the means are not statistically different from one another for the blocks, fertilizer types and fertilizer rates.

Table 8: Analysis of Variance/lsd of the DMC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
P	8	6.7553298	0.8444162	1.69	0.1157
B	2	2.1162013	1.0581006	2.12	0.1278
F	3	2.7884341	0.9294780	1.86	0.1441

R(F)	8	5.9140477	0.7392560	1.48	0.1799
B*F	6	1.6712612	0.2785435	0.56	0.7627
V	2	260.4684785	130.2342393	260.60	<.0001
F	6	2.6733218	0.4455536	0.89	0.5058

F-test is done on blocks, fertilizer and fertilizer rates. The $F_{calculated}$, Fc is compared with $F_{tabulated}F_t$ so as to reject the hypothesis or fail to reject.

Blocks: Ft.05 (2, 6) =5.14

Fc=Bss/B*Fss=2.1162013/1.6712612=1.2662

Fertilizers: Ft.05 (3, 6) =4.76

Fc=Fss/B*Fss=2.7884341/1.6712612=1.6685

Fertilizer rates: Ft.05 (8, 6) =4.15

Fc=R (F)ss/B*Fss=5.9141/1.6713=3.5387

Remarks: For the yield when Fc<Ft we fail to reject Ho: $\mu1=\mu2=........=\mu n$

Hence the means are not statistically different from one another for the blocks, fertilizer types and fertilizer rates.

t Tests (LSD) for Yield

Least Significant Difference 1.4602

Means with the same letter are not significantly different at alpha level 0.05.

t Grouping		Mean	N	F
	A	19.5531	27	1
	A			
B	A	18.5056	27	3
B				

B	17.9585	27	4
C	15.7630	27	2

t Tests (LSD) for DMC

Least Significant Difference 0.3835

Means with the same letter are not significantly different at alpha level 0.05

t Grouping	Mean	N	F
A	26.3111	27	2
A			
B A	26.1852	27	3
B A			
B A	25.9704	27	1
B			
B	25.8444	27	4

t Tests (LSD) for Yield

Least Significant Difference 1.2646

Means with the same letter are not significantly different at alpha level 0.05.

t Grouping	Mean	N	V
A	20.4083	36	1
B	16.7856	36	2
B			
B	16.6413	36	3

t Tests (LSD) for DMC

Least Significant Difference 0.3322

Means with the same letter are not significantly different at alpha level of 0.05.

t Grouping	Mean	N	V
A	28.0861	36	2
B	27.1528	36	3
C	22.9944	36	1

Table 9: Level of Level of Fertilizers and Varieties for Yield and DMC

Level of	Level of	-----------Yield-----------		-----------DMC-----------	
V	F	Mean	Std Dev	Mean	Std Dev
1	1	20.7111111	2.82950722	22.8555556	0.54108944
1	2	18.9888889	1.54510877	23.2111111	0.63135656
1	3	20.3222222	3.25606272	22.8555556	1.22076934
1	4	21.6111111	2.05407792	23.0555556	0.43043905
2	1	19.7777778	4.53321844	27.9333333	0.48733972
2	2	13.9222222	2.68259565	28.3888889	0.50853821
2	3	17.2777778	2.94449817	28.3333333	0.68738635
2	4	16.1644444	2.23010712	27.6888889	0.45946829
3	1	18.1705556	2.01085872	27.1222222	0.80432857
3	2	14.3777778	3.47150104	27.3333333	0.83516465
3	3	17.9166667	2.57269314	27.3666667	0.89721792
3	4	16.1000000	2.59036677	26.7888889	0.86232889

Table 10: Level of Level of Blocks and Fertilizer for Yield and DMC

Level of	Level of	----------Yield----------		----------DMC----------	
B	F	Mean	Std Dev	Mean	Std Dev
1	1	20.2777778	3.47698784	25.8444444	2.27657150
1	2	15.3500000	3.46842904	26.3555556	2.53579924
1	3	17.0888889	3.47605899	25.8777778	3.18032144
1	4	17.7277778	3.85471393	25.7000000	2.41557447
2	1	20.6594444	2.90024616	26.0000000	2.32808935
2	2	16.8388889	3.11857116	26.5777778	2.38263393
2	3	19.3555556	1.86404205	26.3666667	2.28637267
2	4	18.4311111	3.29863019	26.0000000	2.17600551
3	1	17.7222222	3.17422344	26.0666667	2.69953700
3	2	15.1000000	3.94572554	26.0000000	2.42899156
3	3	19.0722222	3.56371568	26.3111111	2.54923736
3	4	17.7166667	3.50740289	25.8333333	2.02484567

Table 11: Level of Level of Rates of Fertilizers and Fertilizer for Yield and DMC

Level of	Level of	----------Yield----------		----------DMC----------	
R	F	Mean	Std Dev	Mean	Std Dev
2.5	1	18.3277778	3.20576737	26.2777778	2.35678689
5	1	19.6722222	4.23535057	25.9555556	2.71113957
10	1	20.6594444	2.24015686	25.6777778	2.19361447
5	2	15.1611111	2.63720707	26.4333333	2.33666429
10	2	15.0555556	4.33290062	26.3111111	2.47459312

15	2	17.0722222	3.26880245	26.1888889	2.56536764
15	3	18.0777778	3.33214562	25.8000000	3.09354166
20	3	17.5888889	2.91684523	26.1444444	2.64533132
25	3	19.8500000	2.98223909	26.6111111	2.24969134
0.24	4	17.2111111	3.32638860	25.7222222	2.11587912
0.28	4	18.4444444	3.53654532	26.0222222	2.31720617
0.32	4	18.2200000	3.72499664	25.7888889	2.19513351

SHORT RAINS SEASONS

YIELD

Table 12: Analysis of Variance/lsd of the YIELD

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
P	3	16.8659262	5.6219754	1.24	0.3023
B	2	69.0144381	34.5072191	7.59	0.0010
F	3	231.0884557	77.0294852	16.94	<.0001
R(F)	8	20.4192909	2.5524114	0.56	0.8062
B*F	6	40.3776723	6.7296120	1.48	0.1962
V	2	33.0795508	16.5397754	3.64	0.0309
V*F	6	99.1842276	16.5307046	3.64	0.0031

F-test is done on blocks, fertilizer and fertilizer rates. The $F_{calculated}$, Fc is compared with $F_{tabulated}F_t$ so as to reject the hypothesis or fail to reject.

Blocks: Ft.05 (2, 6) =5.14

Fc=Bss/B*Fss=69.0144/40.3777=1.7092

Fertilizers: Ft.05 (3, 6) =4.76

Fc=Fss/B*Fss=231.0885/40.3777=5.7232

Fertilizer rates: Ft.05 (8, 6) =4.15

Fc=R (F)ss/B*Fss=20.4193/40.3777=.5057

Remarks: For the yield when Fc<Ft we fail to reject Ho: $\mu 1=\mu 2=\ldots\ldots.=\mu n$

Hence the means are not statistically different from one another for the blocks and fertilizer

Dependent Variable: DMC

Table 13: Analysis of Variance/lsd of the DMC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
P	3	0.7279640	0.2426547	0.52	0.6708
B	2	5.5311772	2.7655886	5.91	0.0041
F	3	1.8581726	0.6193909	1.32	0.2728
R(F)	8	5.9975441	0.7496930	1.60	0.1381
B*F	6	2.2628655	0.3771443	0.81	0.5684
V	2	177.6902136	88.8451068	189.86	<.0001
V*F	6	5.9972346	0.9995391	2.14	0.0586

F-test is done on blocks, fertilizer and fertilizer rates. The $F_{calculated}$, Fc is compared with $F_{tabulated}F_t$ so as to reject the hypothesis or fail to reject.

Blocks: Ft.05 (2, 6) =5.14

Fc=Bss/B*Fss=5.5312/2.2629=2.4443

Fertilizers: Ft.05 (3, 6) =4.76

Fc=Fss/B*Fss=1.8582/2.2629=.8212

Fertilizer rates: Ft.05 (8, 6) =4.15

Fc=R (F)ss/B*Fss=5.9975/2.2629=2.6504

Remarks: For the yield when Fc<Ft we fail to reject Ho: $\mu1=\mu2=........=\mu n$

Hence the means are not statistically different from one another for the blocks, fertilizer types and fertilizer rates.

t Tests (LSD) for Yield

Least Significant Difference 1.1556

Means with the same letter are not significantly different at alpha 0.05.

t Grouping	Mean	N	F
A	15.3728	27	4
A			
A	15.3070	27	1
A			
A	14.3830	27	3
B	11.6022	27	2

t Tests (LSD) for DMC

Least Significant Difference 0.3707

Means with the same letter are not significantly different at alpha level 0.05.

t Grouping	Mean	N	F
A	24.4704	27	2
A			
B A	24.2852	27	3

B A			
B A	24.1259	27	4
B			
B	24.0926	27	1

t Tests (LSD) for Yield

Least Significant Difference 1.0008

Means with the same letter are not significantly different at alpha.

t Grouping	Mean	N	V
A	14.8048	36	1
A			
B A	13.9143.	36	2
B			
B	13.7796	36	3

t Tests (LSD) for DMC

Least Significant Difference 0.3211

Means with the same letter are not significantly different at alpha level 0.05.

t Grouping	Mean	N	V
A	25.4500	36	2
B	24.9639	36	3
C	22.3167	36	1

Table 14: Level of Level of Varieties and Fertilizer for Yield and DMC

Level of	Level of	----------Yield----------		----------DMC----------	
V	F	Mean	Std Dev	Mean	Std Dev
1	1	16.5448889	3.02514278	22.2777778	0.52862505
1	2	10.8366667	1.84836414	22.7000000	0.62048368
1	3	13.8744444	2.14413363	22.4333333	0.65764732
1	4	17.9633333	2.17679811	21.8555556	0.86906719
2	1	15.5150000	1.92655619	25.0777778	0.68333333
2	2	11.7033333	2.91275535	25.9000000	0.82006097
2	3	14.6466667	2.04066778	25.6333333	1.10566722
2	4	13.7922222	1.73208709	25.1888889	0.73048690
3	1	13.8611111	2.29282819	24.9222222	0.68333333
3	2	12.2666667	2.73404462	24.8111111	0.65849154
3	3	14.6277778	1.50459943	24.7888889	0.53489355
3	4	14.3628889	2.34888380	25.3333333	0.65574385

Table 15: Level of Level of Blocks and Fertilizer for Yield and DMC

Level of	Level of	----------Yield----------		----------DMC----------	
B	F	Mean	Std Dev	Mean	Std Dev
1	1	16.7566667	1.38066786	23.7777778	1.15409898
1	2	12.1783333	2.05931724	24.2666667	1.31244047
1	3	15.1550000	2.19112129	24.0777778	1.59669798
1	4	15.6973333	2.01417080	23.5444444	1.69123558
2	1	14.8355556	4.02566178	24.1666667	1.51986842

2	2	13.1455556	1.76887048	24.7111111	1.76878803
2	3	14.5411111	1.37909793	24.5555556	1.59852362
2	4	15.2538889	4.11264041	24.2555556	1.55893482
3	1	14.3287778	0.66458799	24.3333333	1.72046505
3	2	9.4827778	2.25096800	24.4333333	1.57559513
3	3	13.4527778	1.75699159	24.2222222	1.69983659
3	4	15.1672222	1.90021892	24.5777778	2.12354525

Table 16: Level of Level of Rates of Fertilizers and Fertilizer for Yield and DMC

Level of	Level of	-----------Yield------------		------------DMC------------	
R	F	Mean	Std Dev	Mean	Std Dev
2.5	1	14.8394444	2.17820804	24.2777778	1.82124805
5	1	14.9727778	3.70956290	24.0777778	1.24476682
10	1	16.1087778	1.62616795	23.9222222	1.35902334
5	2	11.2838889	2.83077483	24.5000000	1.58429795
10	2	11.3361111	1.98278179	24.7333333	1.29807550
15	2	12.1866667	2.83203990	24.1777778	1.75412213
15	3	14.6766667	1.05649184	24.5333333	2.16217483
20	3	14.1605556	2.06113204	23.9333333	1.25399362
25	3	14.3116667	2.43704226	24.3888889	1.28884100
0.24	4	14.8828889	2.68326412	24.1222222	1.77818572
0.28	4	15.7088889	2.36454247	23.8000000	2.02854628
0.32	4	15.5266667	3.39834886	24.4555556	1.70595363

3.9 CONCLUSIONS

The error term used to determine the F –value is B*Fss. The hypothesis is rejected or fail to be reject at 5% significant level i.e. Fc<Ft, we fail to reject the null hypothesis, H_o:

$\mu 1=\mu_2=......=\mu_n$.

Hence the means are not statistically different from one another.

CHAPTER 4

MULTIVARIATE ANALYSIS OF VARIANCE FOR A SPLIT PLOT DESIGN WITH A COVARIATE

4.1 INTRODUCTION

Multivariate data arise when researches measure variables on each "unit" in their sample. All the variables need to be examined simultaneously in order to uncover the patterns and key features in the data. Multivariate analysis (MANOVA) includes methods that are largely descriptive and others that are primarily inferential aiming to discover what the data has to tell.

A reasonable question to ask is why using more than one criterion variable? In most cases researchers are not interested in single measure of group differences. Rather, there are usually several components, constructs, or behaviors that might be affected by the treatment or that are useful to separate the groups.

MANOVA is concerned with the relationship among sets of dependant variables, and the individuals, which bear them. It is the analysis of observations on several correlated variables, for a number of individuals. Such analysis becomes necessary when one deals with several variables simultaneously. A series of statistical analysis carried out separately for each of the variable is generally not adequate as it ignores the correlation among the variables, it may even be misleading sometimes. On the contrary, MANOVA can through light on relationships; interdependence and relative importance of the characteristics involved and yield more meaning full information. The aim of the statistician undertaking MANOVA is to reduce the number of variables by employing suitable linear combinations on some optimum manner, disregarding the remaining linear combinations in some optimum manner, disregarding the remaining linear combination in the hope that they do not contain much information; the statistician thus reduces the dimensionality of the problem. MANOVA is a conceptually straightforward extension of the well known univariate ANOVA techniques. The major distinction is that in ANOVA one evaluates mean differences on a single dependant criterion variable, where as in MANOVA one evaluates mean differences on two or more dependant criterion variables simultaneously. Although ANOVA and MANOVA are often associated with experimental studies involving a manipulation introduced by experimenter, both techniques are in fact appropriate whenever the researcher question involves a comparisons of mean scores. Like ANOVA, MANOVA is usually conducted as a two-step process. The first step is to test the overall hypothesis of no differences in the means for the different groups. If this test is significant, the second step is to conduct follow-up tests to explain group differences. Although MANOVA allows the researcher to handle multiple dependent variables, these should be selected carefully to accurately measure the effects of interests. In fact, the use of too many dependent variables may hinder the chances of finding a significant result because of low power or it may results in spurious findings due to chance (James and Scott,1985).There are several reasons to use MANOVA in studies investigating mean differences. First, evaluating mean differences on each variable. Secondly, to look at the relationships of the variables rather than in isolation i.e. That is, the researcher wants to evaluate the mean differences on all of the dependant variables simultaneously, while controlling for intercorrelations among them. Thus, one benefit of MANOVA is that by examining both variables together, it may provide a more powerful test than doing separate ANOVAs.

Fitting several variables to the same effects and making tests jointly involving parameters of several dependent variables, the model becomes $Y=X\beta+\varepsilon$. This is when there are k parameters for each p dependent variables and n observations.

Where Y is nXp, Xis nXk, and ε is nXp. Each of the p models is estimated and tested separately.

Considering the joint distribution then p models are tested simultaneously. With nXp errors that are independent across observations but not across dependent variables.

4.2 Assumptions of MANOVA

(i) Samples are randomly selected from population of interest.

(ii) Observations are statistically independent of one another.

(iii) The dependant variables have a multivariate normal distribution within each group. In practice, this can usually be thought of as a requirement that each separate variable follow a normal distribution. In theory, however, univariate normality is necessary but not sufficient for multivariate normality (Carroll, 1961)

iv) The *k* groups have a common within-group population covariance matrix. This assumption is twofold:

(1) The homogeneity of variance assumption of ANOVA must be met for each dependant variable;

(2) The correlation between any two dependant variables must be same in all *k* groups.

When we do lots of tests like that, error inflates. But in many ecological or biological studies, the variables are not independent at all. Many times they have strong actual or potential interactions inflating the error even more highly. In many cases where multiple ANOVAs were done, MANOVA was actually the more appropriate test. With p dependent variables there are nXp errors that are independent across observations but not across dependent variables. MANOVA is specially applied whenever the researcher wants to test the hypothesis concerning multivariate differences in group responses to experimental manipulations.

4.3 Hypothesis Testing

Consider the hypothesis testing in multivariate case, where observations have been obtained for each treatment on several dependent measures. Let p represent the number of dependant variables in the study and μ_{mj} represent the population mean on the variable m for the group j. Notice that m ranges from 1 to p, while j ranges from 1 to k. The multivariate null hypothesis can be written as;

H_O: $\mu_{11} = \mu_{12} = \ldots, = \mu_{1k}$

$\mu_{21} = \mu_{22} = \ldots, = \mu_{2k}$

$\mu_{p1} = \mu_{p2} = \ldots, = \mu_{pk}$

The null hypothesis is that for each variable all k groups have the same population mean.

The alternative hypothesis in this case is that for at least one variable, there is at least one group with a population mean different from the others. All it takes is one equality in the population to make the null hypothesis false.

4.4 THE FOUR TESTS

Four tests are usually constructed: Wilks' lambda, Pillais trace, Hotellings-Lawley trace and Roy's maximum root. If the SAS software is used all the four statistics are reported with F approximations.

1. Wilk's Lambda (λ): will approach zero as the between group differences on the dependent measures increase. The test statistic used in MANOVA is to test whether there

are differences between the means of identified groups of subjects on a combination of dependent variables. It's a direct measure of the proportion of variance in the combination of dependent variables that is unaccounted for by the independent variable (the grouping variable/factor). Wilks' Lambda is a positive-valued statistic that ranges from 0 to 1. Decreasing values of the statistic indicate effects that contribute more to the model

$$\Lambda = \frac{|S_{error}|}{|S_{effect} + S_{error}|}$$

Gives an exact F-statistic.

2. Pillai-Bartlett Trace (a.k.a. Pillai's Trace) (*V*): *V* will increase in value as the between group differences on the dependent measures increase. Pillai's trace is a positive-valued statistic. Increasing values of the statistic indicate effects that contribute more to the model.

$$V = \sum_{i=1}^{s} \frac{\lambda_i}{1+\lambda_i}$$

It gives most conservative F-statistic.

3. Hotelling-Lawley Trace (*T*): *T* will increase in value as the between group differences on the dependent measures increase. Hotelling's trace is the sum of the eigenvalues of the test matrix. It is a positive-valued statistic for which increasing values indicate effects that contribute more to the model.

Hotelling's trace is always larger than Pillai's trace, but when the eigenvalues of the test matrix are small, these two statistics will be nearly equal. This indicates that the effect probably does not contribute much to the model.

$$T = \sum_{i=1}^{s} \lambda_i$$

4. Roy's Maximum Root Criterion (*R*)

Roy's largest root is the largest eigenvalue of the test matrix. Thus, it is a positive-valued statistic for which increasing values indicate effects that contribute more to the model.

Roy's largest root is always less than or equal to Hotelling's trace. When these two statistics are equal, the effect is predominantly associated with just one of the dependent variables, there is a strong correlation between the dependent variables, or the effect does not contribute much to the model.

There is evidence that Pillai's trace is more robust than the other statistics to violations of model assumptions (Olson, 1974).

Each multivariate statistic is transformed into a test statistic with an approximate or exact F distribution.

4.5 Fisher's Least Significant Difference (LSD) Test (post hoc comparison).

You must first conduct the global F-test. If you cannot reject the null hypothesis (i.e., there are no statistically significant differences among the means), then no comparisons are performed. However, if the null hypothesis is rejected, then 2-tailed t-tests between all unique pairs of means are performed. The observed t-statistic is then compared to the critical values obtained from the ANOVA and MANOVA.

Normal distribution-The F test is robust to non-normality.

Linearity-Manova assumes that there are linear relationships among all pairs of dependent variables.

Homogeneity-Homogeneity of variances assumes that the dependent variables exhibit equal levels of variances across the range of predictor variables.

4.6 LIMITATIONS

Outliers may produce either a type I or type II error and give no indication as to which type of error is occurring in the analysis.

The following formula is used to obtain the observed t-statistic:

$$t = \frac{(Y_j - Y_j')}{\sqrt{\left[MS_w\left(1/n_j + 1/n_j'\right)\right]}}$$

where Y_j = mean of group j; Yj' = mean of group j'; MSw = mean squared error within; nj = number of subjects in group j; n_j' = number of subjects in group j'

The rationale behind the lsd technique value comes from the observation that, when the null hypothesis is true, the value of the *t* statistics evaluating the difference between Groups is equal to t. When an ANOVA gives a signicant result, this indicates that at least one group differs from the other groups. Yet, the omnibus test does not indicate which group differences. In order to analyze the pattern of difference between means, the ANOVA is often followed by specific comparisons, and the most commonly used involves comparing two means

4.7 DATA ANALYSIS USING SAS: MANOVA RESULTS

COMBINED SEASONS

Table 17: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Blocks Effect

H = Matrix for Blocks

Statistic	Value	F Value	Num DF	DF	Pr > F
Wilks' Lambda	0.89891884	4.90	4	358	0.0007
Pillai's Trace	0.10288016	4.88	4	360	0.0008
Hotelling-Lawley Trace	0.11044618	4.93	4	213.76	0.0008
Roy's Greatest Root	0.08760041	7.88	2	180	0.0005

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 18: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Variety Effect

H = Matrix for Variety

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.20612046	107.63	4	358	<.0001
Pillai's Trace	0.79645663	59.56	4	360	<.0001
Hotelling-Lawley Trace	3.83902917	171.48	4	213.76	<.0001
Roy's Greatest Root	3.83576963	345.22	2	180	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 19: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall F Effect

H = Matrix for Fertilizer

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.73587443	9.89	6	358	<.0001
Pillai's Trace	0.26651819	9.22	6	360	<.0001
Hotelling-Lawley Trace	0.35567613	10.58	6	236.9	<.0001
Roy's Greatest Root	0.34628684	20.78	3	180	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

Table20: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall R (F) Effect

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.90314983	1.17	16	358	0.2906
Pillai's Trace	0.09830741	1.16	16	360	0.2957
Hotelling-Lawley Trace	0.10562248	1.18	16	289.34	0.2859
Roy's Greatest Root	0.08709697	1.96	8	180	0.0539

Remarks: The statistical test shows the means are non significant, since P>0.05

Table21: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Block*Fertilizer Effect

H = Type III SSCP Matrix for B*F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.95630090	0.67	12	358	0.7765
Pillai's Trace	0.04412782	0.68	12	360	0.7739

Hotelling-Lawley Trace	0.04524766	0.67	12	275.38	0.7777
Roy's Greatest Root	0.03059416	0.92	6	180	0.4834

Remarks: The statistical test shows the means are non significant, since P>0.05.

Table22: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Variety*Fertilizer Effect

H = Matrix for V*F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.89811840	1.65	12	358	0.0771
Pillai's Trace	0.10395138	1.64	12	360	0.0776
Hotelling-Lawley Trace	0.11113437	1.65	12	275.38	0.0776
Roy's Greatest Root	0.08355180	2.51	6	180	0.0236

Remarks: The statistical test shows the means are non significant, since P>0.05.

Table 23: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Fertilizer Effect

H = Matrix for F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.73587443	9.89	6	358	<.0001
Pillai's Trace	0.26651819	9.22	6	360	<.0001
Hotelling-Lawley Trace	0.35567613	10.58	6	236.9	<.0001
Roy's Greatest Root	0.34628684	20.78	3	180	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

LONG SEASONS

Table 24: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Blocks Effect

H = Matrix for BLOCKS

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.91029196	1.71	4	142	0.1514
Pillai's Trace	0.09116151	1.72	4	144	0.1489
Hotelling-Lawley Trace	0.09695193	1.71	4	84.171	0.1547
Roy's Greatest Root	0.07592053	2.73	2	72	0.0718

Remarks: The statistical test shows the means are non significant, since P>0.05.

Table 25: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Variety Effect

H = for VARIETY

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.11202956	70.56	4	142	<.0001
Pillai's Trace	0.92486973	30.97	4	144	<.0001
Hotelling-Lawley Trace	7.59684429	134.24	4	84.171	<.0001
Roy's Greatest Root	7.55323769	271.92	2	72	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 26: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Fertilizer Effect

H = Matrix for Fertilizer

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.67434542	5.15	6	142	<.0001

Pillai's Trace	0.33744540	4.87	6	144	0.0001
Hotelling-Lawley Trace	0.46543472	5.47	6	92.91	<.0001
Roy's Greatest Root	0.42421812	10.18	3	72	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 27: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall R(F) Effect

H = Matrix for R(F)

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.73044817	1.51	16	142	0.1041
Pillai's Trace	0.29065155	1.53	16	144	0.0966
Hotelling-Lawley Trace	0.34013654	1.49	16	112.65	0.1143
Roy's Greatest Root	0.17617005	1.59	8	72	0.1443

Remarks: The statistical test shows the means are non significant, since P>0.05.

Table 28: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall B*F Effect

H = Matrix for B*F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.87711311	0.80	12	142	0.6481
Pillai's Trace	0.12650615	0.81	12	144	0.6395
Hotelling-Lawley Trace	0.13597749	0.80	12	107.4	0.6530
Roy's Greatest Root	0.09026299	1.08	6	72	0.3807

Remarks: The statistical test shows the means are non significant, since P>0.05

Table 29: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall V*F Effect

H = Matrix for V*F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.83279790	1.13	12	142	0.3378
Pillai's Trace	0.17432470	1.15	12	144	0.3282
Hotelling-Lawley Trace	0.19221890	1.13	12	107.4	0.3469
Roy's Greatest Root	0.12227065	1.47	6	72	0.2017

Remarks: The statistical test shows the means are non significant, since P>0.05.

Table 30: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Fertilizer Effect

H = Matrix for F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.67434542	5.15	6	142	<.0001
Pillai's Trace	0.33744540	4.87	6	144	0.0001
Hotelling-Lawley Trace	0.46543472	5.47	6	92.91	<.0001
Roy's Greatest Root	0.42421812	10.18	3	72	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

SHORT RAINS SEASON

Table 31: Criteria and F Approximations for the Hypothesis of No Overall Blocks Effect

H = MANOVA Test Matrix for Blocks

Statistic	Value	F Value	Num DF	Den DF	Pr > F

Wilks' Lambda	0.71010753	7.09	4	152	<.0001
Pillai's Trace	0.29714033	6.72	4	154	<.0001
Hotelling-Lawley Trace	0.39803073	7.53	4	90.17	<.0001
Roy's Greatest Root	0.37048086	14.26	2	77	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 32: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Variety Effect

H = Matrix for Variety

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.15818496	57.54	4	152	<.0001
Pillai's Trace	0.84226820	28.01	4	154	<.0001
Hotelling-Lawley Trace	5.31884895	100.63	4	90.17	<.0001
Roy's Greatest Root	5.31831030	204.75	2	77	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 33: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Fertilizer Effect

H = Matrix for Fertilizer

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.56211344	8.46	6	152	<.0001
Pillai's Trace	0.43996249	7.24	6	154	<.0001
Hotelling-Lawley Trace	0.77530724	9.76	6	99.575	<.0001
Roy's Greatest Root	0.77051423	19.78	3	77	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 34: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall R (F) Effect

H = Matrix for R (F)

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.80192381	1.11	16	152	0.3518
Pillai's Trace	0.20521903	1.10	16	154	0.3591
Hotelling-Lawley Trace	0.23809411	1.12	16	120.83	0.3447
Roy's Greatest Root	0.19160781	1.84	8	77	0.081

Remarks: The statistical test shows the means are non significant, since P>0.05.

Table 35: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall B*F Effect

H = Matrix for B

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.85145960	1.06	12	152	0.3975
Pillai's Trace	0.15312574	1.06	12	154	0.3943
Hotelling-Lawley Trace	0.16906857	1.06	12	115.18	0.3995
Roy's Greatest Root	0.12649582	1.62	6	77	0.1520

Remarks: The statistical test shows the means are non significant, since P>0.05.

Table 36: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall V*F Effect

H = Matrix for V*F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.65537775	2.98	12	152	0.0009

Pillai's Trace	0.36759907	2.89	12	154	0.0013
Hotelling-Lawley Trace	0.49077869	3.08	12	115.18	0.0008
Roy's Greatest Root	0.40399903	5.18	6	77	0.0002

Remarks: The statistical test shows the means are significant, since P<0.05.

Table 37: MANOVA Test Criteria and F Approximations for the Hypothesis of No Overall Fertilizer Effect

H = Matrix for F

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.56211344	8.46	6	152	<.0001
Pillai's Trace	0.43996249	7.24	6	154	<.0001
Hotelling-Lawley Trace	0.77530724	9.76	6	99.575	<.0001
Roy's Greatest Root	0.77051423	19.78	3	77	<.0001

Remarks: The statistical test shows the means are significant, since P<0.05.

CONCLUSION

In all seasons when P<0.05 then it is significant. F Statistic for Roy's Greatest Root is an upper bound whereas F Statistic for Wilks' Lambda is exact. Manova assumes that there are linear relationships among all pairs of dependent variables.

CHAPTER 5

TESTING FOR OPTIMAL FERTILIZER LEVELS

5.1 INTRODUCTION

For quantitative treatments e.g. different levels of fertilizer it is not appropriate to make mean comparisons using the t-test or multiple comparison tests. In this case appropriate regression and response surface techniques should be used. It is important to know how much yield increases with a unit increase of fertilizer; in such a situation an appropriate response curve is fitted.

Regression analysis is the most appropriate technique in comparing several levels of a quantitative factor. When regression is significant, no multiple comparisons is necessary as all treatments including intermediate ones not used in the experiment are significantly different in their effects.

5.2 POLYNOMIALS

A polynomial is a function consisting of successive powers of the independent variables. The general form of a polynomial relationship of Y (dependent) and an independent variable Xis represented by;

$$Y=\alpha+\beta_1X+\beta_2X^2+\ldots\ldots+\beta^nX^n$$

Where;

Y=response variable, α=intercept and β=partial regression coefficient for the i^{th} degree polynomial. The first degree polynomial is called linear e.g. $Y=\alpha+\beta x$, only β is significant. There will be an increase in Y of β units for every unit increase in X.However; there is the question on the cost of applying the factor X on a particular level.

5.3 THE OPTIMALYIELD LEVEL

The second degree polynomial is called quadratic if only β_1 and β_2 or β_2 is significant, Gomez &Gomez (1984).If the lowest level of a factor is zero (control), and there are two alternatives:

(i)Fit a regression curve at all levels. Likely to give a curvilinear relation

(ii)Fit a regression to the non-zero levels. Results to a linear relationship

5.4 QUADRATIC REGRESSION

The quadratic regression is fitted to the data in the form;

$Yi=a+bX_i+cX_i^2$.

Finding the derivatives of the above equation above, it results to;

$\frac{dy}{dx}$=B+2cX

At $\frac{dy}{dx}=0$, then=$X_O=-b/2c$.

The maximum point of X_0 is realized when $\frac{d^2y}{dx^2}<0$

If $\frac{d^2y}{dx^2}>0$ then X_0 is at minimum.

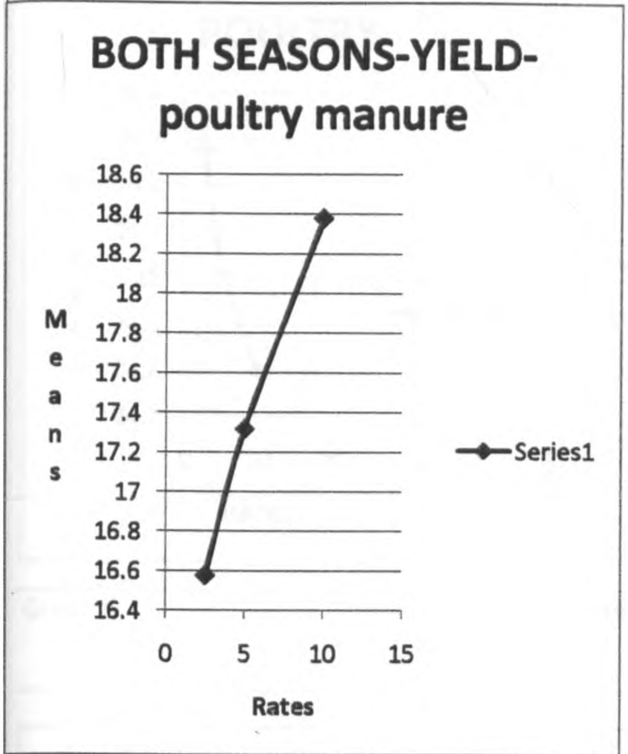
The maximum yield is given by $Y=a+bX_0+cX_0^2$

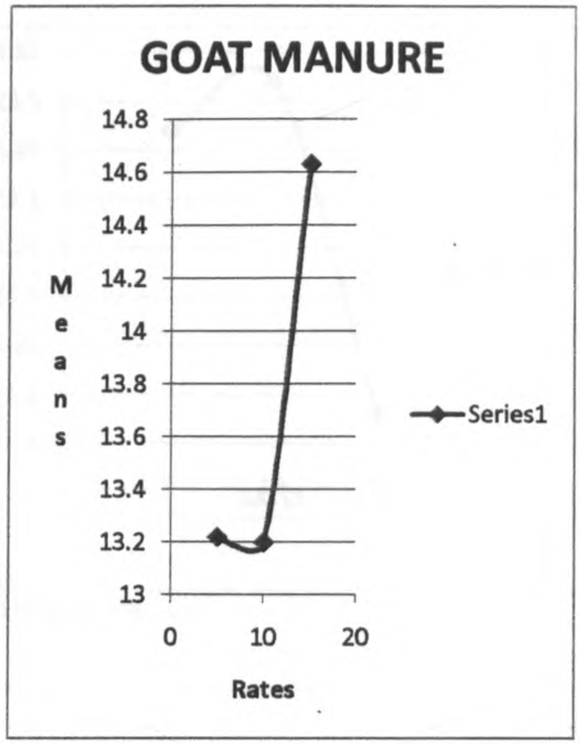
5.5 GRAPHICAL OUTPUT

LINE GRAPHS OF MEANS AGAINST RATES

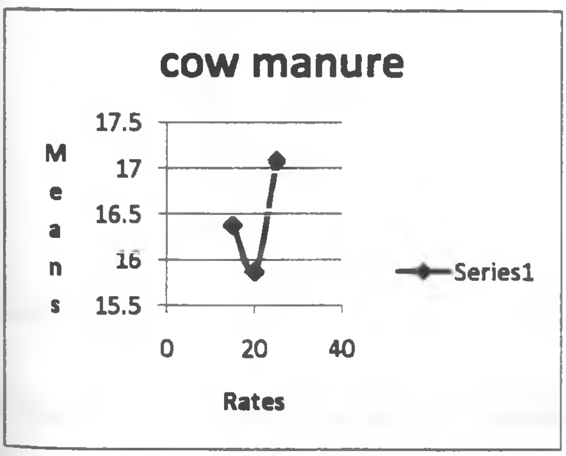
1. BOTHSEASONS (LONG AND SHORT RAINS)

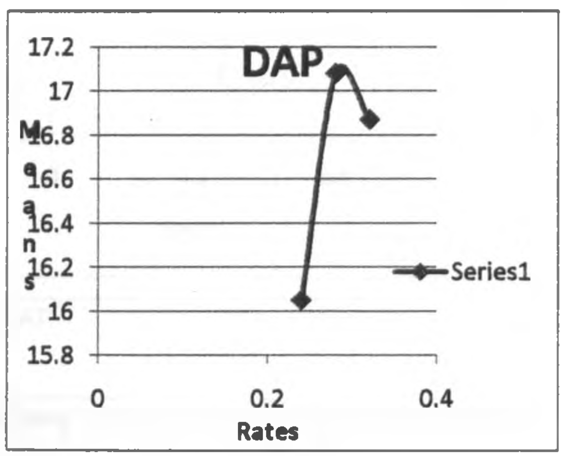
The graphs below shows the relationship between rates of manure/fertilizer against the means of total yield when both seasons are combined using four types of manure. The turning point is observed. Absence of maximum turning point implies further study to be done so as to trace a possible maximum or isolate incompatible results.





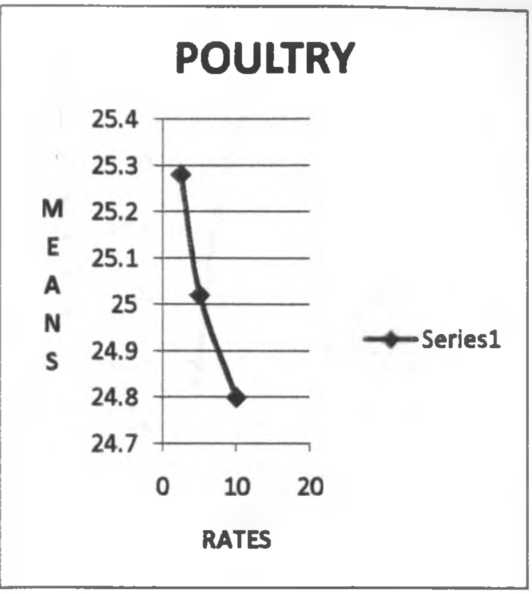
GRAPH1	Graph2



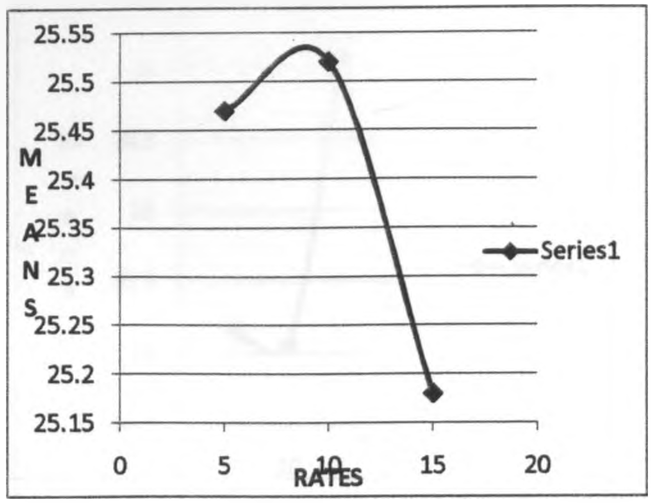


Graph 3	Graph 4

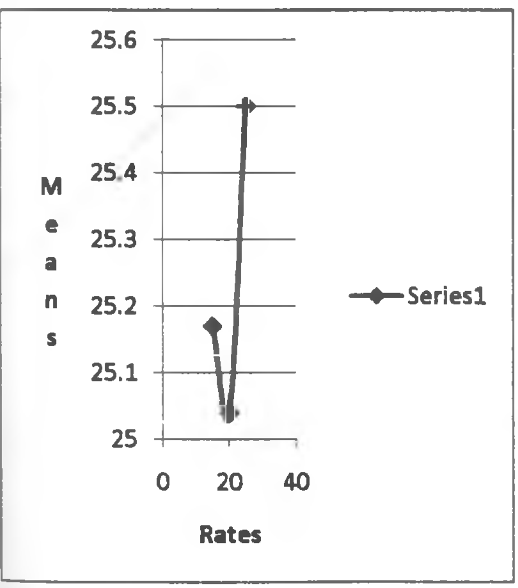
(ii)GRAPHS OF DMC-Dry matter content



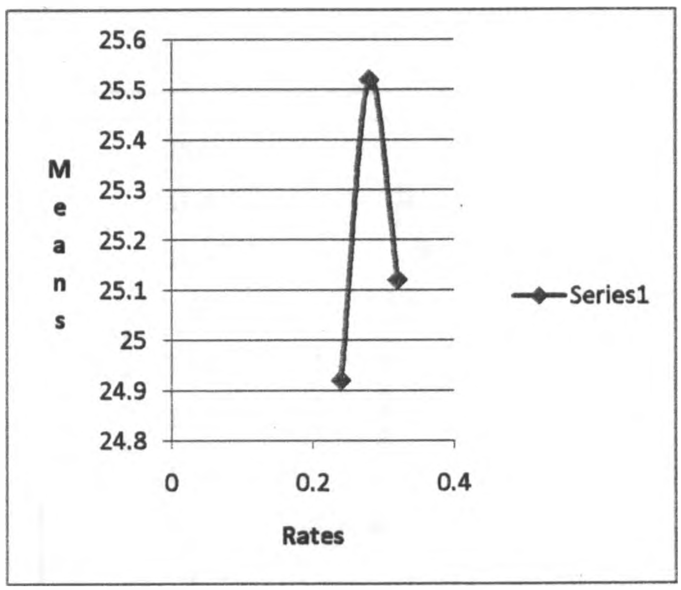
Graph 5



GRAPH 6 of goat manure

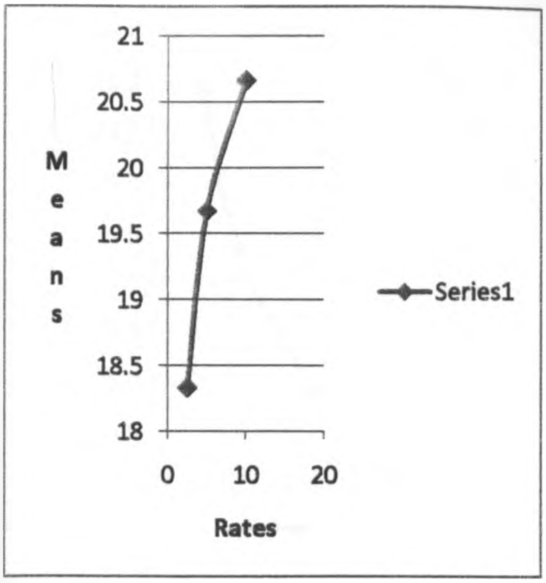


Graph 7 of cow manure

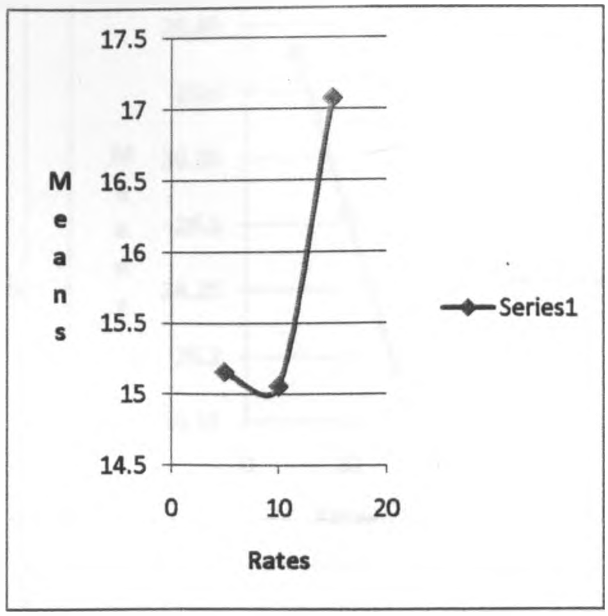


Graph 8 of DAP

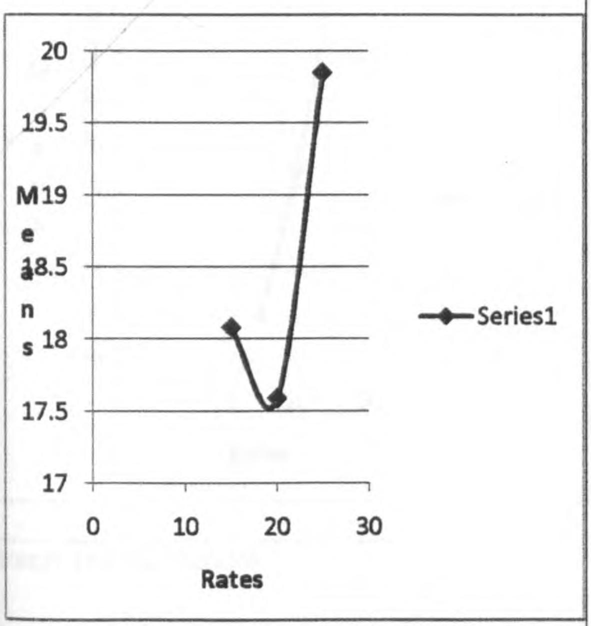
2. Graphical representation of the four treatments during long rains showing the means of the yield against the fertilizer rates.



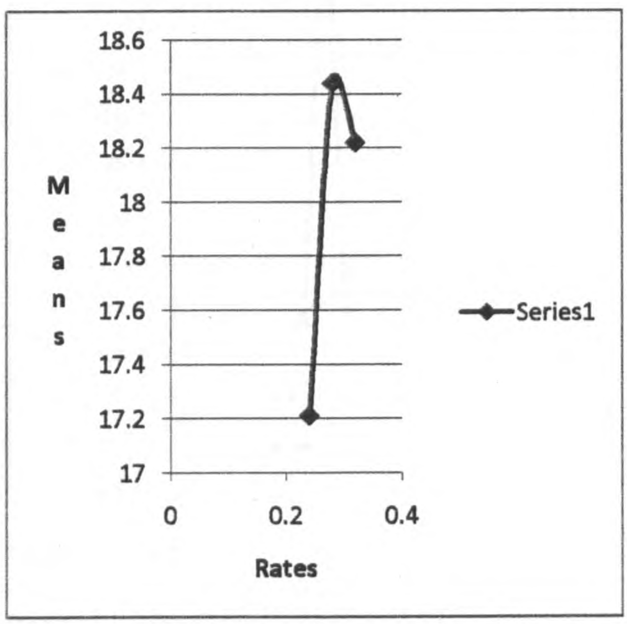
Graph 9-poultry manure



Graph 10-goat manure

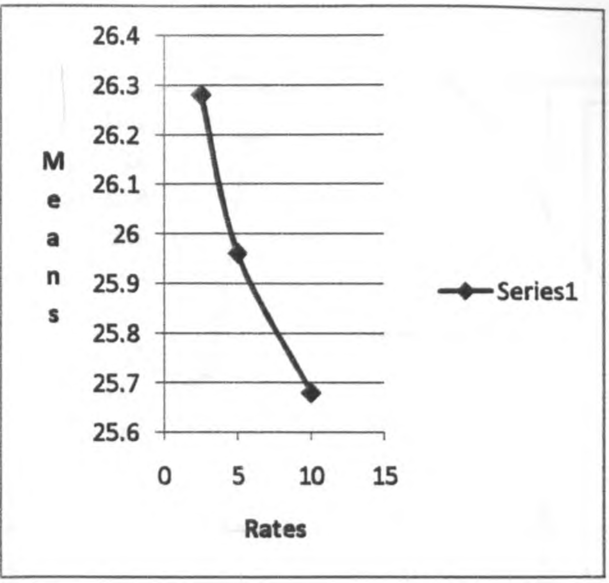
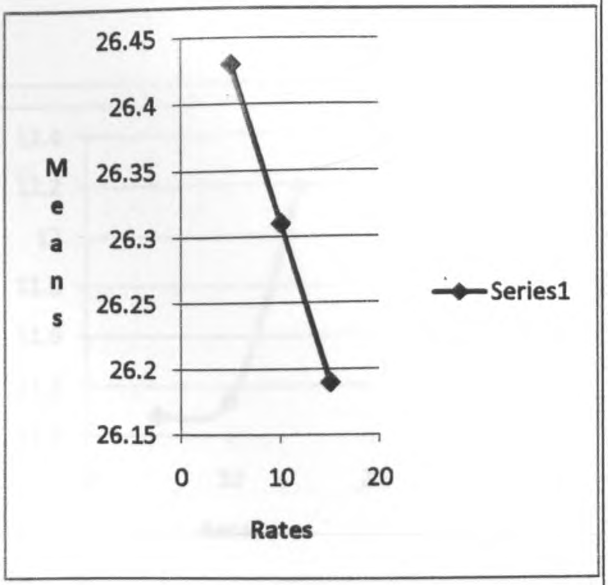
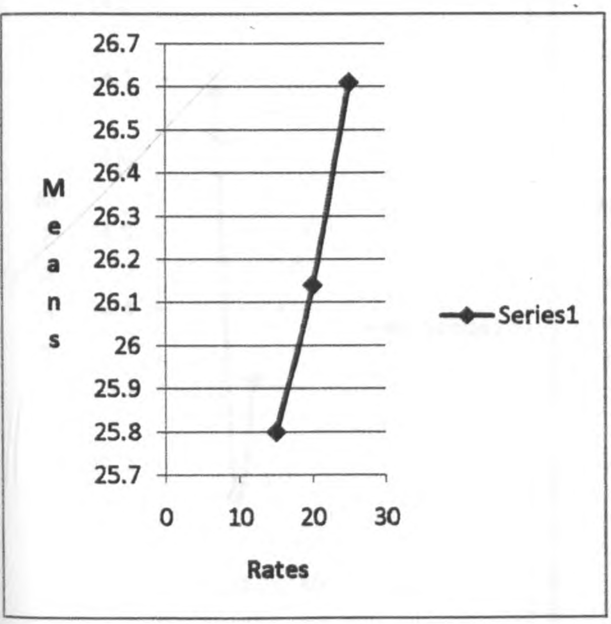
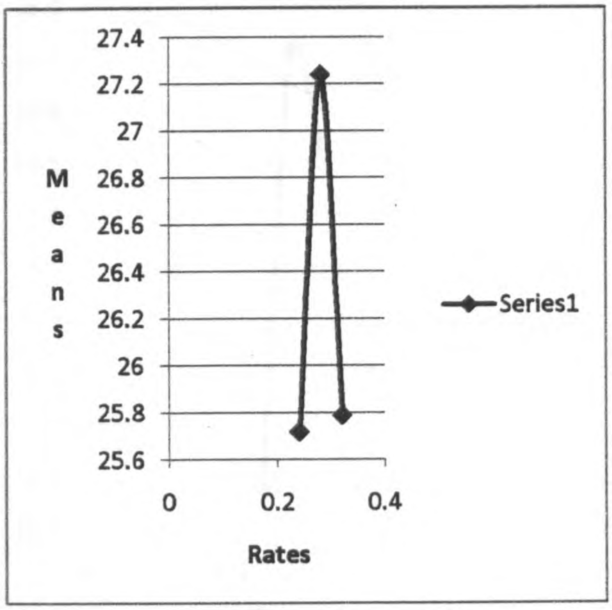


Graph11-cow manure



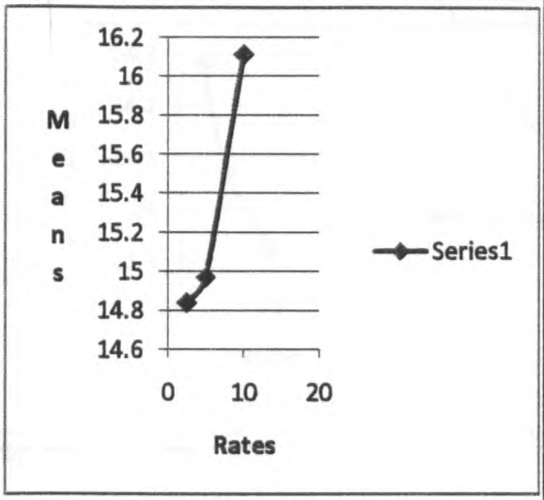
Graph12-DAP

(ii)GRAPHS OF DMC DURING LONG RAINS SEASONS

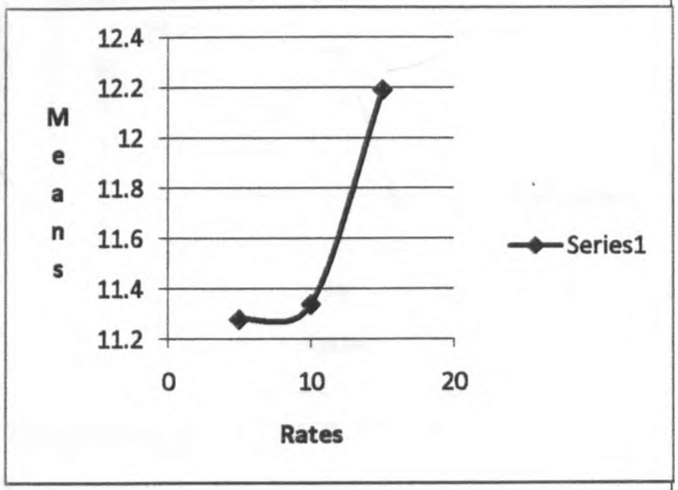
	
Graphs 13-Poultry	Graph 14-Goat
	
Graph-15-Cow manure	Graph 16-DAP

3. Short rains graphs

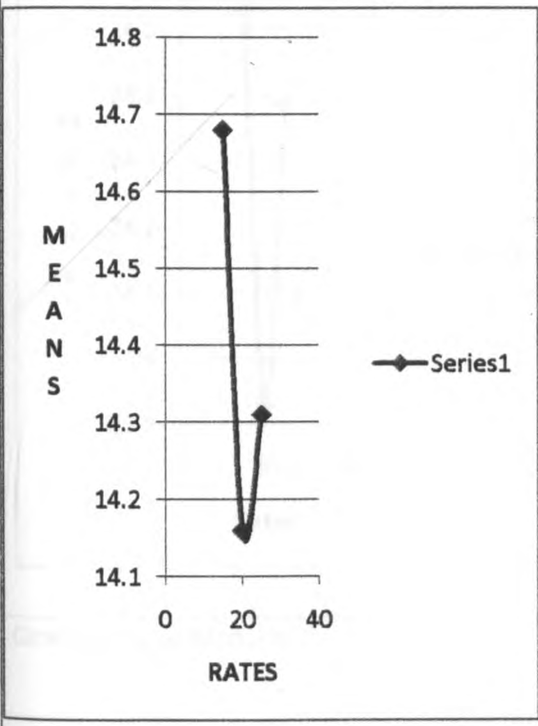
(i)YIELD



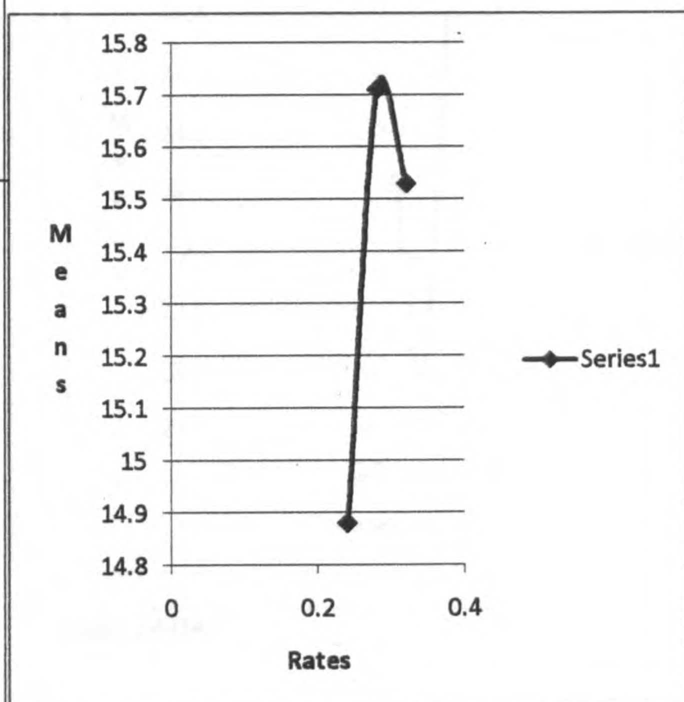
Graph 17-Poultry Manure



Graph 18-Goat Manure

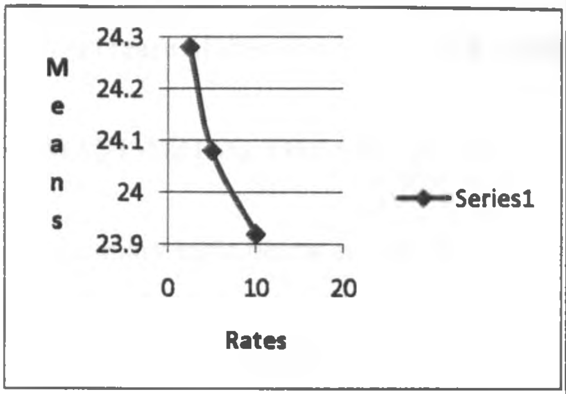


Graph 19-Cow Manure

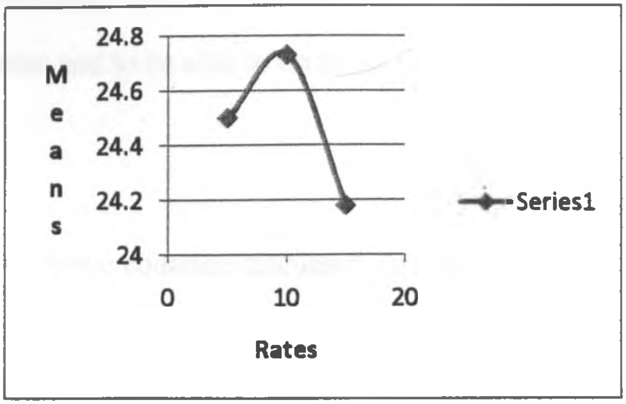


Graph 20-DAP

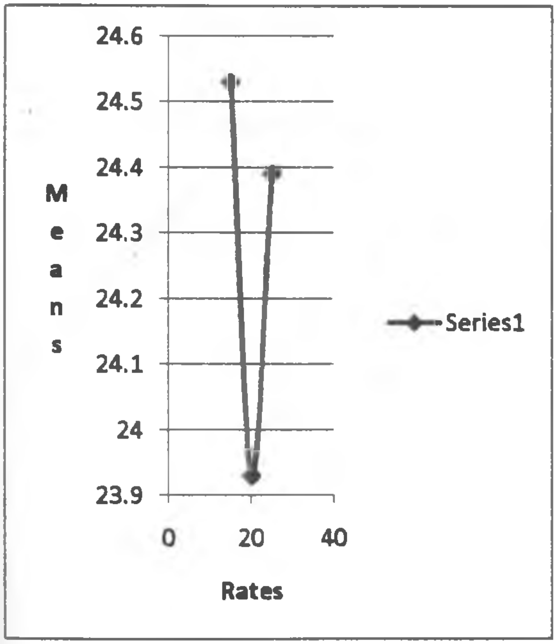
(ii)DMC Graphs



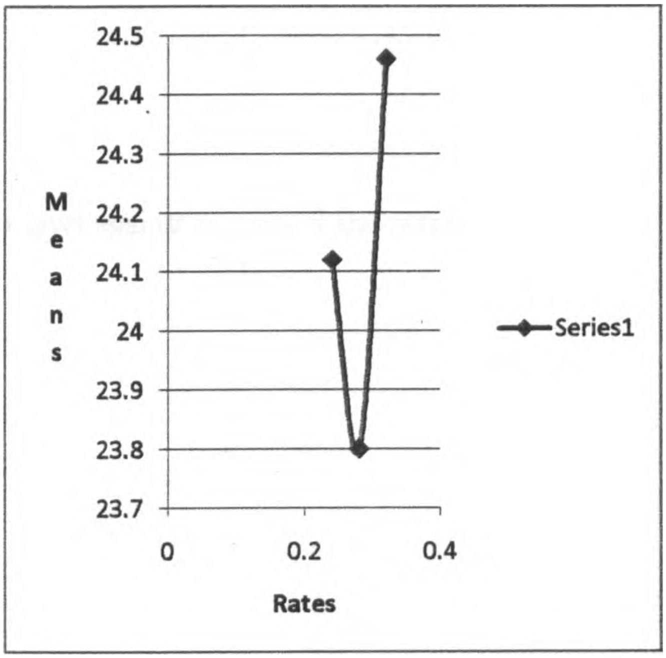
Graph 21-Poultry



Graph 22-Goat



Graph 23-Cow Manure



Graph 24-DAP

The graphs above reveals there is need to find the optimal levels i.e. determine X_0 and Y maximum for each fertilizer level and specific season. However, some cases require further study-increase of the rates to reach the turning point and to be able to establish the optimal level.

5.6 MAXIMIZING THE OUTPUT

The summary table below establishes using the quadratic equation discussed earlier the ;

(i) a=the intercept

(ii) b=level(X)

(iii) c=level*level

(iv) X0=Optimal point

(v) Y=Maximum Yield in each fertilizer level against the season and output.

Table 38: Optimal levels of the fertilizers

Seasons	Output	Fertilizer	A	b	c	X_0(MAX)	Y(MAX)
Combine	Yield	DAP	-16.17	227.25	-387.5	.2932	17.15
Combine	DMC	DAP	.32	177.5	-312.5	.284	25.525
Combine	DMC	GOAT	25	.132	-.008	8.25	25.55
SHORT RAINS	DMC	GOAT	23.49	.28	-.0156	8.9744	24.75
SHORT RAINS	YIELD	DAP	-15.72	219	-381.25	.2872	15.7270
LONG RAINS	YIELD	DAP	-20.62	266.375	-453.125	.2939	18.5279
LONG RAINS	DMC	DAP	-45.77	520.625	-928.125	.2805	27.24

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The summary in chapter five captures the best season to plant the varieties and the type of fertilizer that can result to maximum output. Yield is highest during long rains at28.24tons per ha, followed by combine seasons at 17.15tons per ha and then short rains at 15.727 tons per ha for DAP. DAP is superior than any other fertilizer type, in all seasons.DMC is maximum during long rains at 27.21 tons per ha using DAP whereas at combine season goat manure has the highest at 25.55tons per ha.

6.2 RECOMMENDATIONS

I recommend the use of DAP in all seasons for optimum output of yields as well as DMC.There is need to establish the economical value for such production. It's possible to have highest output but at a very heavy cost. Probably the second or third highest output is not significantly different from the first yet it requires low cost then it is prudent to use the one with the lowest cost. Further research is required to establish the optimal level for those that showed linearity.

Food and Agriculture Organization of the United Nations, International Year of the Potato, 2008

Gomez. A. K. and Gomez. A. A., 1984, *Statistical Procedure for Agriculture Research.* 2nd

Government of Kenya (2010), Agriculture Sector Development Strategy (ASDS) 2010-2020. Ministry of Agriculture, Nairobi Kenya.

Gupta A. K., Rajender Parsad and Batra. P. K., 2004, Status of Agricultural Experimentation in the National Agricultural Research System

Kenya Agricultural Research Institute (KARI). National Potato Research Centre, Tigoni Annual Report, 2005.

Kiiya, W.W., Mureithi J.G. and Kiama, J.M (2006). Improving production of Irish potato (Solanum tuberosum, L.) in Kenya: The use of green manure legumes for soil fertility Improvement.

Kleinbaum, D.G.etal (2007) Applied Regression Analysis and Multivariate Methods (ISBN: 0534209106/0-534-20910-6).

Mardia, K.V.; J.T.Kent, J.M.Bibby (1979)*Multivariate Analysis.* Academy Press

Mulla D. J., Bhatti A. U., and Kunkel R. 1990, Methods for removing spatial variability

Nganga NM, Kipkoech D, Nyongesa M, Kinyae PM (2008) The status of potato production and marketing in Bomet and Molo Districts, Kenya.

Noureldin, N. A., Abdel Halim, A. A., El-Baially, M. E., and Mohammed, S. G. A., 2000, A

Tukey, John Wilder (1977).*Exploratory Data Analysis.*Addison-Wesley.ISBN 0-201-07616-0.

www.potato2008.org.

Martinez and Pell, P.(2000). Nutrient fluxes from a soil treatment process for pig slurry. *British Society of Soil science Journal*. Soil use and land management. 16, 100 –107.

MOA and R.D (Ministry of Agriculture and Rural Development. (2000). Annual Report (Unpublished).

Nandasaba J., Lusweti C.M., Nkonge C., Wanjekeche E.O. and Rees D.J. (1999). Participatory evaluation of potato varieties for increased yields and cash generation. KARI/DFID NARP II end of Project conference 23rd-26th March 1999 Nairobi Kenya.

APPENDICES

Appendix 1: The potato raw results of yield and dry matter content for both seasons

BLOCKS	VARIETY	FERTILIZER TYPE	FERTILIZER LEVEL	PLANT COUNT	TOTAL	PERCENT DRY MATTER
1	1	1	2.5	28	17.325	22.2
1	1	1	5	30	18.9	22.4
1	1	1	10	27	16.3	22.2
2	1	1	2.5	30	12.3	22.7
2	1	1	5	29	21.25	22.2
2	1	1	10	30	19.8	22.2
3	1	1	2.5	29	13.99	21.2
3	1	1	5	29	13.65	23.2
3	1	1	10	30	15.389	22.2
1	2	1	2.5	29	17.8	24.6
1	2	1	5	30	17.2	24.6
1	2	1	10	30	17.625	24.1
2	2	1	2.5	30	16.7	26.1
2	2	1	5	30	12.35	24.4
2	2	1	10	30	15.39	25.1
3	2	1	2.5	29	13.75	25.6

3	2	1	5	30	14.105	25.6
3	2	1	10	29	14.715	25.6
1	3	1	2.5	30	15.96	24.4
1	3	1	5	29	14.55	24.6
1	3	1	10	28	15.15	24.9
2	3	1	2.5	30	11.83	26.1
2	3	1	5	28	8.65	24.1
2	3	1	10	30	15.25	24.6
3	3	1	2.5	30	13.9	25.6
3	3	1	5	30	14.1	25.6
3	3	1	10	29	15.36	24.4
1	1	2	5	30	11.75	22.7
1	1	2	10	27	10.15	23.6
1	1	2	15	27	12.88	21.9
2	1	2	5	28	12.42	22.7
2	1	2	10	30	12.9	23.4
2	1	2	15	30	11.28	22.2
3	1	2	5	28	9.25	22.7
3	1	2	10	30	9.15	23.2
3	1	2	15	28	7.75	21.9
1	2	2	5	30	15.15	26.1
1	2	2	10	28	14.275	25.1
1	2	2	15	30	9.95	25.1

2	2	2	5	30	11.11	27.1
2	2	2	10	30	12.95	26.1
2	2	2	15	30	15.7	26.8
3	2	2	5	30	7.675	25.1
3	2	2	10	30	8.9	26.6
3	2	2	15	30	9.62	25.1
1	3	2	5	30	13.8	24.9
1	3	2	10	28	9.3	24.6
1	3	2	15	29	12.35	24.4
2	3	2	5	30	13.5	25.1
2	3	2	10	30	12.25	23.9
2	3	2	15	30	16.2	25.1
3	3	2	5	29	6.9	24.1
3	3	2	10	29	12.15	26.1
3	3	2	15	30	13.95	25.1
1	1	3	15	29	14.62	21.2
1	1	3	20	30	15.9	21.9
1	1	3	25	29	11.945	23.2
2	1	3	15	29	14.6	22.4
2	1	3	20	29	14.19	22.9
2	1	3	25	30	16.38	23.2
3	1	3	15	30	15.55	22
3	1	3	20	28	10.455	22.7

3	1	3	25	29	11.23	22.4
1	2	3	15	30	15.3	25.6
1	2	3	20	30	17.6	25.1
1	2	3	25	30	18.38	25.1
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2	2	3	20	30	13.15	25.6
2	2	3	25	30	14.1	25.4
3	2	3	15	30	13.22	26.1
3	2	3	20	30	13	23.6
3	2	3	25	30	14.02	26.6
1	3	3	15	29	16.3	25.1
1	3	3	20	30	14.1	25.1
1	3	3	25	29	12.25	24.4
2	3	3	15	30	15.15	24.9
2	3	3	20	30	13.35	24.4
2	3	3	25	30	16.9	24.6
3	3	3	15	28	14.3	25.9
3	3	3	20	30	15.7	24.1
3	3	3	25	29	13.6	24.6
1	1	4	0.24	30	19.22	22.2
1	1	4	0.28	29	17.1	20.2
1	1	4	0.32	28	17.65	21.9
2	1	4	0.24	30	18.15	22.2

2	1	4	0.28	28	19.65	22.2
2	1	4	0.32	30	22	22.2
3	1	4	0.24	30	14.6	21.3
3	1	4	0.28	29	17.53	21.2
3	1	4	0.32	29	15.77	23.3
1	2	4	0.24	28	14.75	24.1
1	2	4	0.28	30	14.9	24.6
1	2	4	0.32	30	16.1	24.6
2	2	4	0.24	30	10.945	25.6
2	2	4	0.28	30	12.42	25.1
2	2	4	0.32	29	14.41	25.4
3	2	4	0.24	29	11.575	25.6
3	2	4	0.28	30	14.83	25.1
3	2	4	0.32	30	14.2	26.6
1	3	4	0.24	28	15.056	24.6
1	3	4	0.28	29	12.95	25.1
1	3	4	0.32	28	13.55	24.6
2	3	4	0.24	29	15.7	25.6
2	3	4	0.28	30	14.6	25.1
2	3	4	0.32	30	9.41	24.9
3	3	4	0.24	30	13.95	25.9
3	3	4	0.28	29	17.4	25.6
3	3	4	0.32	30	16.65	26.6

1	1	1	2.5	30	24.1	23.2
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1	1	1	10	30	23.8	22.9
2	1	1	2.5	30	18.8	22.9
2	1	1	5	30	18.6	22.9
2	1	1	10	30	19.7	23.2
3	1	1	2.5	29	16.1	23.6
3	1	1	5	30	20.1	21.7
3	1	1	10	29	21	22.4
1	2	1	2.5	28	18.75	28.1
1	2	1	5	24	13.85	28.8
1	2	1	10	28	21.35	27.3
2	2	1	2.5	30	19.55	28.1
2	2	1	5	28	27.15	28.3
2	2	1	10	24	23.4	27.6
3	2	1	2.5	23	12.3	28.1
3	2	1	5	26	21.05	27.3
3	2	1	10	27	20.6	27.8
1	3	1	2.5	30	19.75	26.4
1	3	1	5	25	19.3	26.6
1	3	1	10	28	17.4	26.4
2	3	1	2.5	25	19.05	27.8
2	3	1	5	29	18.45	26.8

2	3	1	10	27	21.235	26.4
3	3	1	2.5	28	16.55	28.3
3	3	1	5	30	14.35	28.3
3	3	1	10	26	17.45	27.1
1	1	2	5	30	17.2	23
1	1	2	10	30	20.2	22.7
1	1	2	15	25	20.25	24.1
2	1	2	5	30	17.35	23.6
2	1	2	10	28	21.2	23.4
2	1	2	15	30	19.6	23.4
3	1	2	5	30	16.85	23.6
3	1	2	10	30	18.75	23.2
3	1	2	15	30	19.5	21.9
1	2	2	5	25	13.3	28.8
1	2	2	10	25	11.95	28.6
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2	2	2	15	27	12.6	29.1
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3	2	2	10	22	10.4	27.6
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2	3	2	10	27	13.1	28.6
2	3	2	15	30	18.55	27.6
3	3	2	5	29	12.05	27.1
3	3	2	10	25	9.15	26.8
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1	1	3	20	30	18.8	22.7
1	1	3	25	27	21.2	23.2
2	1	3	15	29	19.9	22.7
2	1	3	20	28	20.2	23.2
2	1	3	25	28	21.2	24.6
3	1	3	15	29	24.5	23.2
3	1	3	20	30	19.1	22.7
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1	2	3	15	25	14.05	29.1
1	2	3	20	30	13.3	28.8
1	2	3	25	26	16.7	28.1
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2	2	3	20	28	22.35	28.6
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3	2	3	15	29	17.5	27.3
3	2	3	20	22	15.9	27.3
3	2	3	25	27	20.2	29.1
1	3	3	15	29	19.05	27.1
1	3	3	20	29	14.5	26.1
1	3	3	25	27	22.6	27.8
2	3	3	15	30	18.55	27.6
2	3	3	20	27	18.4	26.8
2	3	3	25	27	18.1	27.1
3	3	3	15	27	19.55	26.6
3	3	3	20	27	15.75	29.1
3	3	3	25	27	14.75	28.1
1	1	4	0.24	30	22	22.7
1	1	4	0.28	30	22.2	22.2
1	1	4	0.32	29	20.8	22.9
2	1	4	0.24	30	21.15	23.2
2	1	4	0.28	30	23.85	23.4
2	1	4	0.32	30	22.4	22.9
3	1	4	0.24	28	19.6	23.6
3	1	4	0.28	29	17.9	23.4
3	1	4	0.32	30	24.6	23.2
1	2	4	0.24	28	14.9	27.6
1	2	4	0.28	22	12.25	27.8

1	2	4	0.32	25	17	28.1
2	2	4	0.24	26	14.5	27.8
2	2	4	0.28	28	18.75	27.8
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3	2	4	0.24	27	18.55	28.1
3	2	4	0.28	22	18.35	28.1
3	2	4	0.32	23	14.7	26.8
1	3	4	0.24	28	16.65	26.8
1	3	4	0.28	30	20.75	27.3
1	3	4	0.32	27	13	25.9
2	3	4	0.24	27	15.5	26.6
2	3	4	0.28	30	16.45	27.1
2	3	4	0.32	23	16.8	28.1
3	3	4	0.24	29	12.05	25.1
3	3	4	0.28	29	15.5	27.1
3	3	4	0.32	26	18.2	27.1

Appendix 2: Sample SAS statements used for ANOVA

```
DATA POTATO;
INPUT B     V     F     R     P     Yield     Dmc;
CARDS;
      1     1     1     2.5   28    17.325    22.2
      1     1     1     5     30    18.9      22.4
```

```
 .      .      .      .      .      .        .
 .      .      .      .      .      .        .
 2      1      1      5      29     21.25    22.2
 2      1      1      10     30     19.8     22.2
;
PROC GLM;
CLASS B F V R;
MODEL Yield Dmc=P B F R(F) B*F V F*V;
Means F/LSD;
Means R/LSD;
Means V/LSD;
Means F*V/LSD;
Means R(F)/LSD;
Run;
```

Appendix 3: Sample SAS statements used for MANOVA

```
DATA POTATO;
INPUT B      V      F      R      P YIELD       DMC;
CARDS;
 1      1      1      2.5    28     17.325   22.2
 .      .      .      .      .      .        .
 3      3      4      0.28   29     17.4     25.6
 3      3      4      0.32   30     16.65    26.6
;
PROC GLM;
CLASS B V F R P;
```

```
MODEL YIELD DMC=P B F R(F) B*F V F*V;

MANOVA H=B/PRINTE;

MANOVA H=V/PRINTE;

MANOVA H=F/PRINTE;

MANOVA H=R/PRINTE;

MANOVA H=B*F/PRINTE;

MANOVA H=F*V/PRINTE;

MANOVA H=R(F)/PRINTE;

MANOVA H=P/PRINTE;

RUN;
```

Appendix 4: Sample SAS statements used for optimal levels(quadratic)

```
DATA YIELD;

INPUT LEVEL YIELD;

CARDS;

      .24   25.72

      .28   27.24

      .32   25.79

;

PROC GLM;

MODEL YIELD=LEVEL LEVEL*LEVEL;

RUN;
```