



**A MULTILEVEL (COMBINED ANALYSIS) FOR A REPEATED
DATA IN TWO SEASONS ON DRY MATTER YIELDS OF COMMON
FODDER GRASSES IN WESTERN KENYA**

BY

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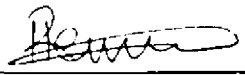
FALCULTY OF SCIENCE

SCHOOL OF MATHEMATICS

**THIS DESSERTATION IS SUBMITTED IN PARTIAL
FULFILMENT FOR THE DEGREE OF MASTER OF SCIENCE IN
BIOMETRY**

DECLARATION

I the undersigned declare that this project is my original work and has not been presented as a degree in any other university.

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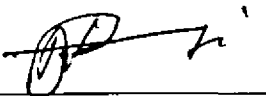
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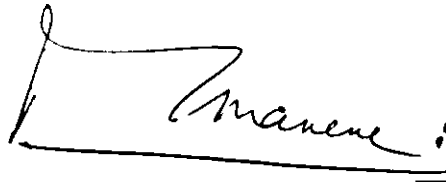
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DEDICATION

I dedicate this degree to my parents Mr. & Mrs. Ngumo, my brothers and sisters whose prayers and support has made me come all this way.

ACKNOWLEDGEMENT

I thank the almighty God for the good health and sound mind throughout my research work.

I greatly appreciate the guidance from my Supervisors Mr. James Ngugi Mwangi and Prof. Manene. It is through their support, advice and valuable comments that I was able to learn and complete my research successfully.

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ABSTRACT

Fodder grasses are the most common crops fed to dairy animals in Kenya. Although not directly used for human consumption, they are the source of protein and fat i.e. meat, milk and other dairy products that are available to human beings through intermediaries like cattle, sheep, goats, poultry etc. Performance of four grass fodder varieties on two different rainy seasons was evaluated to determine seasonal effects. The fodder grass varieties included in the study were; Bana grass, Cameroon grass, Bajra grass, and Giant Panicum (P. Maximum). Two harvests (cuts) were made in each of the two seasons. The main objective of the study were to determine DM (dry matter) yield of the four varieties in the two different rainy seasons and to determine the effects of cutting times on fodder yields. Kenya has two very different rainy seasons; Long rain season and short rain season. The total mean yield of the four fodder varieties was high in long rain season (7.14 t/ha) compared to the total mean yield of the short season (2.63 t/ha) in the first cut. The mean yield of second cut during short rain season is higher (7.33 t/ha) compared to the mean yield of Long rain (5.97 t/ha). Season had significant effect on the yield ($p < 0.0001$ for cut 1 and $p = 0.0067$ for cut 2) of fodder grass varieties. The significant reduction in yield during the short rain season could be due to inadequate moisture causing reduction in vegetative growth. Examining the effect of seasons and treatments interaction of the two harvests (cut 1 and cut 2), showed significance ($p = 0.0067$ and $p < 0.001$) respectively) meaning that a number of fodder grass varieties produced higher dry matter yield in one of the season than the other. The results of this study indicate that harvest management of fodder grass should vary according to season. There is need of farmers in Kenya to beef up moisture requirement during short rain season to have adequate surplus of fodder crop throughout the year.

CHAPTER 1

INTRODUCTION

1.1. Background

Agriculture is the backbone of the Kenyan economy. It contributes approximately 25% of GDP, employing 75% of the national labour force. Over 80% of the Kenyan population lives in rural areas and make a living, directly or indirectly, from agriculture (*Patrick O. Alila and Rosemary Atieno, 2006*). Many of these people are smallholder farmers who live in areas of high potential for agriculture and forest production with an annual rainfall of more than 750mm, spreading from central Kenya through the central Rift valley to Western Kenya and at the extreme east the coastal strip (Smith & Orodho, 2000). Kenya has the most developed smallholder dairy system in sub-Saharan Africa with an estimated dairy herd of 3 million head. Most dairy cattle are crosses of Friesian, Ayrshire and other exotic dairy breeds with local zebu. Dairy is important in the livelihoods of many farm households in terms of generating income and employment. Smallholder dairies (mainly family farms of less than 10 hectares and fewer than 10 dairy animals are concentrated in the crop-dairy systems of the high potential areas, producing about 60 percent of the milk and contributing over 80 percent of the marketed output (*Peeler & Omoro, 1997; Thorpe et al., 2000*). The system is characterized by small crop-livestock farms. An important feature of the system is that milk is a cash crop and the manure produced is used to fertilize food and cash crops which include coffee, tea, sugarcane, wheat, vegetables, pyrethrum, bananas, cut flowers and other horticultural crops. The main food crop is maize but others include sorghum, millet, beans, potatoes and vegetables.

Smallholder dairying has increased in recent years because of liberalization in the dairy sub-sector and because low cash crop prices has made dairying an important income earner.

However, development of smallholder dairy systems in Kenya's high potential areas has been marked by declining farm sizes, upgrading to dairy breeds and an increasing reliance on purchased feeds both concentrates and forages (Staal *et al.* 1998). The major cattle feeds are natural grass and planted fodder, mainly Napier grass (*Pennisetum purpureum*). With the increasing human population, available grazing is decreasing and planted areas of fodder grass are becoming the main fodder source (Orodho, 1990). Where farms are small, cattle are confined and fed by cut-and-carry, also referred to as zero-grazing (Baltenweck *et al.*, 1998). Napier grass (*Pennisetum purpureum*) and Giant Panicum (*P. Maximum*) are increasing becoming importantly cultivated fodder grasses for dairy cattle. Other fodders include maize, Sudan grass, sugarcane tops, banana pseudo stems and regumes.

An experiment to study the effect of annual rainy season on the fodder grass yield variety was conducted in Kitale, western Kenya. The fodder grass varieties included in the study were; Bana grass, Cameroon grass, Bajra grass, and Giant Panicum (*P. Maximum*). Bana grass is the most popular and is characterized by short succulent stems with broad leaves and has the least tendency to be stemy at maturity. French Cameroon which grows up to 3 m is stemy and hairy. Bajra fodder grass is a widely grown type of millet. It is important forage of arid and semi-arid region. *P. maximum* is regarded as most valuable plant and is extensively used in making hay. It is a perennial, tufted grass with a short, creeping rhizome. In Kenya the average dry matter yields vary between 10-40 t/ha per year depending on soil fertility, climate and management (Schreuder *et al.* 1993).

Kenya has two very different rainy seasons; Long rain season and short rain season. The long rain season is from March to May which brings heavy down pours. The short rainy season is from October to December. In these two seasons temperature doesn't vary as much and so the seasons seem to be defined more by the amount of rainfall.

The performance of the 4 grass fodder varieties on the two different rainy seasons was evaluated to determine seasonal effect. Two harvests (cuts) were carried out each of the two seasons. The main objective of the study were to; 1. Determine DM (dry matter) yield of the 4 varieties in the two different rainy seasons, 2. Determine the effects of cutting times on fodder yields of 4 fodder grass varieties.

1.2. The Research Problem

Milk and dairy products are important in the Kenya diet and the demand for milk is rising sharply with an ever-increasing population. Forages are not directly used for human consumption but they are the source of protein and fat from meat, milk and other dairy products that become available to human beings through intermediaries like cattle, sheep, goats, poultry etc. Since feeding alone accounts for 60-70% of the total cost of milk production, availability of adequate nutritious fodder coming from cheaper sources assumes greater importance. Considering the huge gap between the demand and supply of green nutritious fodder and quality dry matter along with the static or decreasing land availability, efforts at various research institutes are directed to intensify forage production per unit, which can be achieved through improved high yielding varieties and better management practices. The major challenge is to overcome the inadequate quantity and quality of these cultivated fodders.

The yield of fodder crop depends upon the type of soil, its fertility and availability of adequate water in time. The yield also depends upon fodder varieties and harvesting practices. When a farmer is deciding on the number of daily animals to keep, he has to consider the amount of fodder required per day. Moreover, the productivity of these dairy animals is determined by the quality and quantity of the fodder (G. Tarawali, and M.A. Mohamed-Saleem, 1983). Thus there is need to have enough supply of fodder crop throughout the year to maintain dairy production.

The research questions in our study will be;

- i. Does annual rainy season influence production of fodder grass in Kenya?
- ii. Do the fodder grasses differ significantly in yield and DM production?
- iii. Is there any interaction between the fodder grasses and Seasons?

1.3. Research Objective

The main objectives of this experiment were to study the effect of two rainy seasons on dry matter (DM) yields of common fodders grasses in Kenya and examine different cutting times variation.

1.4. Hypothesis

Hypothesis 1:

Null hypothesis: There is no significant difference between mean dry matter yields of fodder grass harvested in different seasons.

Alternative hypothesis: There is a significant difference between mean dry matter yields of fodder grass harvested in different seasons.

Hypothesis 2:

Null hypothesis: There is no significant difference between mean dry matter yields of fodder grass cutting periods.

Alternative hypothesis: There is a significant difference between dry matter mean yields of fodder grass cutting periods.

Hypothesis 3:

Null hypothesis: There is no significant difference between two ways and three ways Interaction for the three factors of fodder, Season and Cutting.

Alternative hypothesis: There is a significant difference between two ways and three ways Interaction for the three factors of fodder, Season and Cutting.

1.5. Literature Review

1.5.1. Introduction

This section highlights similar studies done before to determine effects of fodder grass production. We will also explore the four different fodder grass varieties used as treatment in this study.

A number of authors, including Crowder and Chheda (1977) and Ruthenberg (1974) have listed useful forage species for livestock production in the humid tropics, taking into account dry matter production, ease of establishment, length of growing season, quality of dry-season feed provided, and in some cases ease of eradication when fodder plants invade neighboring food crops. Among the grasses, recommended species include *Brachiaria ruziziensis*, Napier grass (*Pennisetum purpureum*), *Panicum maximum* and *Pennisetum purpureum*, as well as their hybrids with *P. typhoides*, *Chloris gayanus* and *Cenchrus ciliaris*.

The dry and wet seasons in East Africa influence the dry matter yield and quality of Napier grass fed to dairy cattle. Water deficit depresses forage yield and has a negative effect on crude protein (CP) concentration (Buxton & Mertens, 1995). Anindo & Potter (1994) confirmed this and indicated that seasonal variation could cause drastic changes in DM yield. He found that DM yield (tones DM/ha/day) were 0.178 in wet season and 0.025 during the dry season.

V. A. Oyenuga studied the effect of stage of growth and frequency of cutting on the yield and chemical composition of *Panicum maximum* fodder grass in Nigeria. A progressive reduction in yields of dry matter and of green fodder was shown with successive cuttings, particularly in the case of the more frequently cut grasses; the yields obtained during the 1964 seasons were lower than those of 1963.

J. Glover and W. R. Birch studied the effect of rainfall and age on the yield of some unfertilized fodder crops in Kenya. He found that Increased rainfall, whether annual or seasonal, led to increased yields of all crops, although the extent of the increase depended on the type of crop, the nature of the rainy season, whether long or short, and in particular the age of the perennial crops. All the perennials aged at similar rates and ageing led to reduced yields.

P.B. Barnes et al;(1985) in his study found that dry matter yields increased as re-growth period lengthened and it was noteworthy that *Panicum maximum* dry matter yields in the dry season were higher than in the wet season. DM yields (kg/ha) of grasses at 3, 6, 9 and 12 weeks after cutting in the wet season was 0.573,0.864,0.865,0.2301 respectively, at 6 and 12 weeks after cutting in the dry season was 1.693, 2.650 respectively and total yield of 5.0 tonnes DM/ha in 1992/93. This may have been caused by the high rainfall from September to November

1.5.2. Fodder grass variety

The Intensive fodder production systems based on Napier grass (*Pennisetum purpureum*) are increasingly becoming important to farmers who keep improved dairy cattle in the semi-arid region of western Kenya that receive between 500 - 800 mm of annual rainfall (Njarui and Wandera, 2000). Dry matter yield of the grass is generally low due to poor soil fertilization regimes and erratic rainfall. The fodder is productive during the wet season and the nutritive

value is generally low and does not meet the animal production requirements throughout the year. Various fodder grass characteristics and maintenance are discussed in the sections below.

1.5.2.1. Bana Grass (*Pennisetum purpureum* x *Pennisetum typhoides*)

In Queensland, Bana Grass is more commonly known as Cow Cane and is a hybrid species of *Pennisetum purpureum* and *Pennisetum typhoides*. Bana Grass is similar in appearance to sugar cane with pale green leaves up to three centimeters in width and can grow as high as four meters. It is densely tufted with shorter underground runners and the seeds are located in cylindrical spikes, which are yellow in colour and up to thirty centimeters long.

Bana grass grows on a wide range of soil types provided fertility is adequate. Grows best in deep, well-drained friable loams with a pH of 4.5-8.2 (mean 6.2). It is normally only found in areas with rainfall >1,000 mm, and on river banks in areas of lower rainfall. Although it is extremely drought tolerant by virtue of deep root system, it needs good moisture for production. It produces best growth between 25 and 40°C, and little growth below about 15°C, with growth ceasing at 10°C. Tops killed by frost, but re-grows with onset of warm, moist conditions. Grows from sea level to 2,000 m altitude. Normally cut at 15 cm above ground, although difficult to maintain constant cutting height. Cattle eat mostly leaf. Proportions of leaf decrease and stem increases, with age and height. Should not be allowed to grow >1.5 m before cutting, to ensure cut material is mostly leaf.

Bana Grass (*Pennisetum purpureum*)

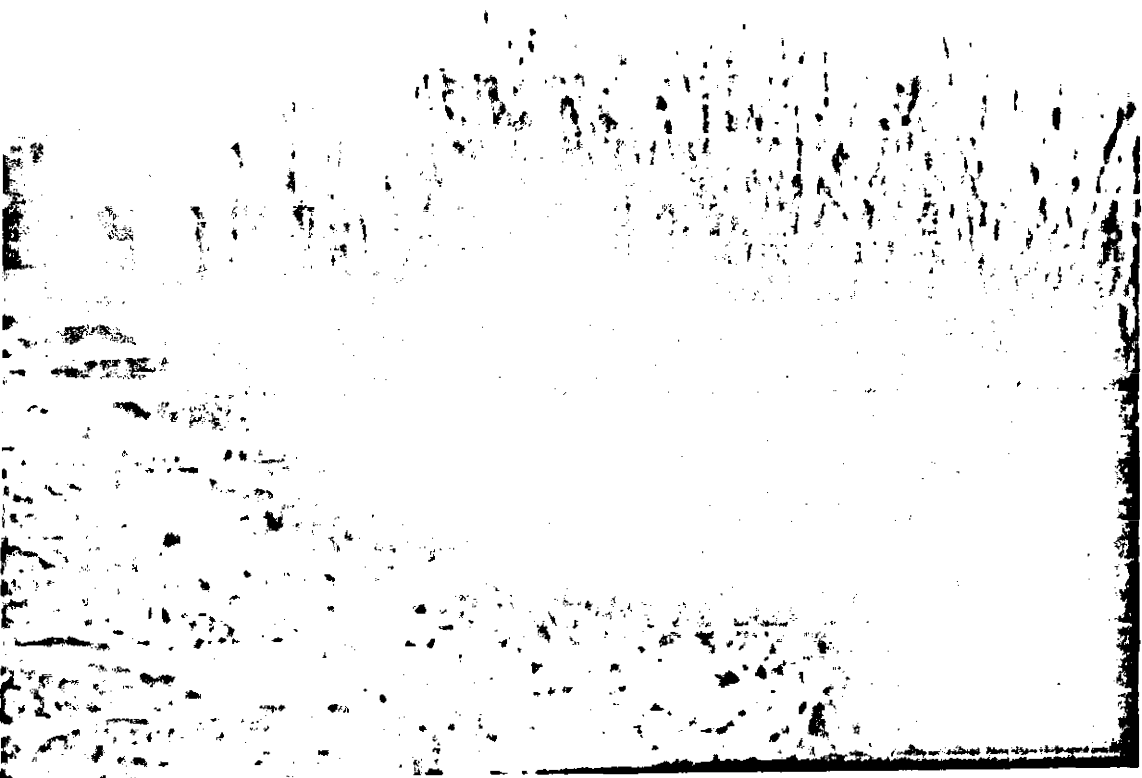


Photo: Ramesh W. S. Pande © 2012

1.5.2.2. French Cameroon Grass

French Cameroon is a robust perennial bunchgrass which can form dense clumps; has large flat leaves that may be 30-90 cm long and up to 3 cm broad. It is a shy breeding grass and seed yields are usually very low - rarely more than 1-2 kg/ha Pure Germinating Seed (PGS) – therefore it is usually established vegetative from stem cuttings or crown divisions.

French Cameroon grass



1.5.2.3. Guinea Grass (*Panicum maximum*)

Panicum maximum (guinea grass) is native to Africa but this grass was introduced to almost all tropical countries as a source of animal forage. It grows well on a wide variety of well drained soils of good fertility and it is suitable to stop soil erosion. It can survive quick moving fires which does not harm the underground roots and drought because of the deep, dense and fibrous root system. This tufted grass species is highly palatable and attracts many seed-eating birds to the garden. It is regarded as the most valuable fodder plant and is extensively used to make hay.

Panicum maximum is a perennial, tufted grass with a short, creeping rhizome. The stems of this robust grass can reach a height of up to 2 m. As the stems bend and nodes touch the ground, roots and new plants are formed. The leaf sheaths are found at the bases of the stems and are covered in fine hairs. It remains green until late into winter. The leaf blades are up to 35 mm wide and taper to a long fine point. The inflorescence is a large multi-branched, open panicle with loose, flexuous branches. The lower branches of the inflorescence are arranged in a whorl. The lower floret is usually male with a well-developed palea (upper bract enclosing flower). The fertile (female) upper lemma is pale. Spikelets are green to purple and flowering occurs from November to July.

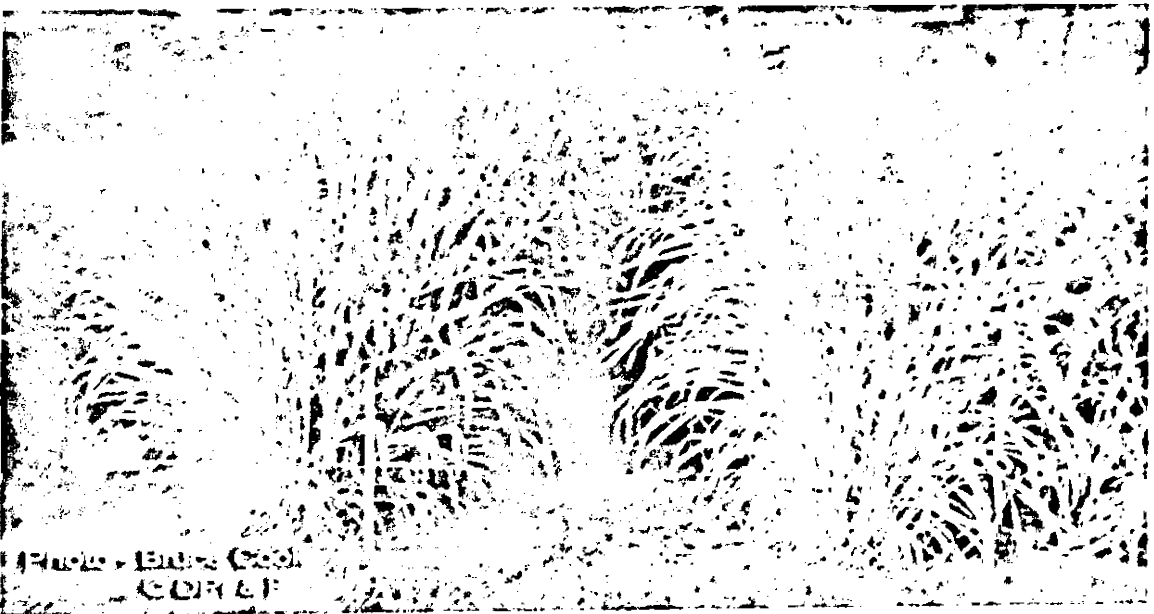
This species varies in size and hairiness and may also vary to a lesser extent in growth habit. There are distinct forms of *Panicum* in South Africa, but the transversely wrinkled upper floret or seed of *P. Maximum*, distinguishes it from all other *Panicum* species.

Guinea grass prefers fertile soil and is well adapted to a wide variety of conditions. It grows especially well in shaded, damp areas under trees and shrubs and is often seen along rivers. It is most frequently found in open woodland, but also grows in parts of Mixed and Sour Bushveld.

It is considered to be the most valuable fodder plant in the area where it is distributed. It has a high leaf and seed production and is very palatable to game and livestock. It is widely cultivated as pasture and is especially used to make good quality hay. If it receives adequate water, it grows rapidly and occurs in abundance in vied that is in a good condition.

This grass can easily be cultivated from seed that is obtainable from seed distributors. Sow seed in spring and early summer in fertile, well-prepared soil. It prefers shade and damp areas and will do well under trees and shrubs. If the grass is already established and conditions are favorable, it will multiply quickly and form a luxuriant growth. It may become a persistent weed, especially in cultivated areas such as sugarcane fields. It should be controlled in the seedling stage, as it is very difficult to remove later when the grass has reached maturity. It is not an ornamental grass, but can be planted successfully in plant containers around the home to attract seed-eating birds.

Panicum maximum (guinea grass)



1.5.2.4. Bajra (Pearl Millet)

Pearl millet (*Pennisetum glaucum*) is the most widely grown type of millet in Africa. Pearl millet is well adapted to production systems characterized by drought, low soil fertility, and high temperature. It performs well in soils with high salinity or low pH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal crops grow. It is an important forage crop of the arid and semi-arid regions of the country. It is fed to the cattle either as green or dry. It hybridizes very well with elephant grass (*Pennisetum purpureum* Schum.) which is believed to be of African origin. Bajra is highly drought tolerant and can grow well in the areas with a rainfall of 25–75 cm.

The crop is in tufted clumps, the culms slender, 15–75 cm high; leaf blades linear or linear-lancelets, 5–30 cm long, 3–10 mm broad, glabrous or with some long white hairs toward base on upper surface; spike erect, cylindrical, golden-brown in colour, 1–15 cm long, 6–12 mm broad.

The recommended spacing is 45 cm between rows and 10–12 cm between plants. The seed rate is 5 kg/ha. The crop responds well to applied nutrients. Besides recommended dose of fertilizers, application of 8–10 t/ha of FYM is also helpful as it conserves moisture. Application of 20kg ZnSO₄ /ha enhances fodder yield. Foliar application of ZnSO₄/ha at pre-flowering stage also increases grain and fodder yield.

BAJRA (PEARL MILLET)



1.6. Methodology

1.6.1. Experimental site

The experiment was conducted at Kenya Agricultural Research Institute (KARI), Kitale Research centre (1°N and 35°E, altitude 11860m. Mean annual total rainfall is 717 mm, with a bimodal pattern; the long rains (LR) occurs from March to May and the short rains (SR) from October to December with peaks in April and November respectively. There is a distinct dry season between the LR and SR seasons which last for 4 months (June - September) where rainfall is unlikely and in January and February when amount of rainfall is negligible. The land on which the experiment was established had been under natural fallow. Analysis of the soil from the site indicated that it was sandy clay loam with pH of 5.6 (1:2.5 soil: water); organic matter 2.33% and soil nutrients (mg kg^{-1}) P 22.02; K 458.68; Ca 770.3; Mg 262.75; and (%) N 0.22.

1.6.2. Treatment and design

A randomized complete block design with four replications was used. Treatments consisted of Bana grass, Cameroon grass, Bajra grass, and P. Maximum grass planted as pure stand without intercropping with any other crop.

1.6.3. Measurement

The first rainy season from April to May and the first dry season from June to September were regarded as establishment. Prior to onset of the second wet season in October, 2002; the fodder grass were harvested for standardization. Thereafter, they were harvested after 4 weeks for the first cut in short rain season. After another 4 weeks from the first week second harvest was done. Same procedure of grass cutting was repeated for the long rain season.

The grass was cut using hand sickles, put in paper bags, dried at 105°C for 48 hours in an oven and dry weight taken.

1.6.4. Statistical Analysis

All quantitative data was input in excel spread sheet. Data collected was statistically evaluated by analysis of variance using Statistical Analysis Systems (SAS). Combine analysis for repeated measures was used to analyse the dry matter yield of the fodder grasses.

CHAPTER 2

EXPLORATORY DATA ANALYSIS

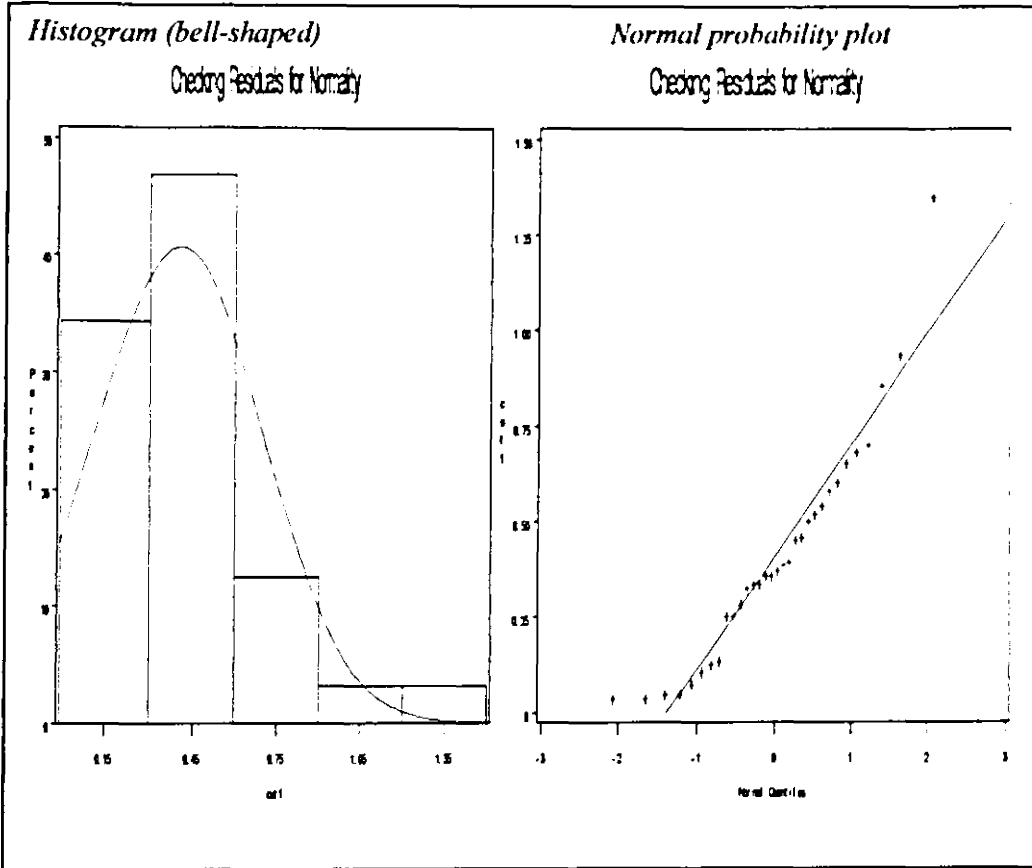
2.0. Introduction

Exploratory data analysis will be done to confirm whether the data conforms to the underlying assumptions of linear model before fitting a linear model for combined analysis for repeated measures. Repeated measure MANOVA carries the standard set of assumption associated with an ordinary analysis of variance: multivariate normality, homogeneity of covariate matrices, and independence. This section will look at different EDA for the different cuts of fodder grasses per season to test for normality and correlation. Most EDA techniques will be graphical in nature with a few quantitative techniques.

2.1. Check the data for normality

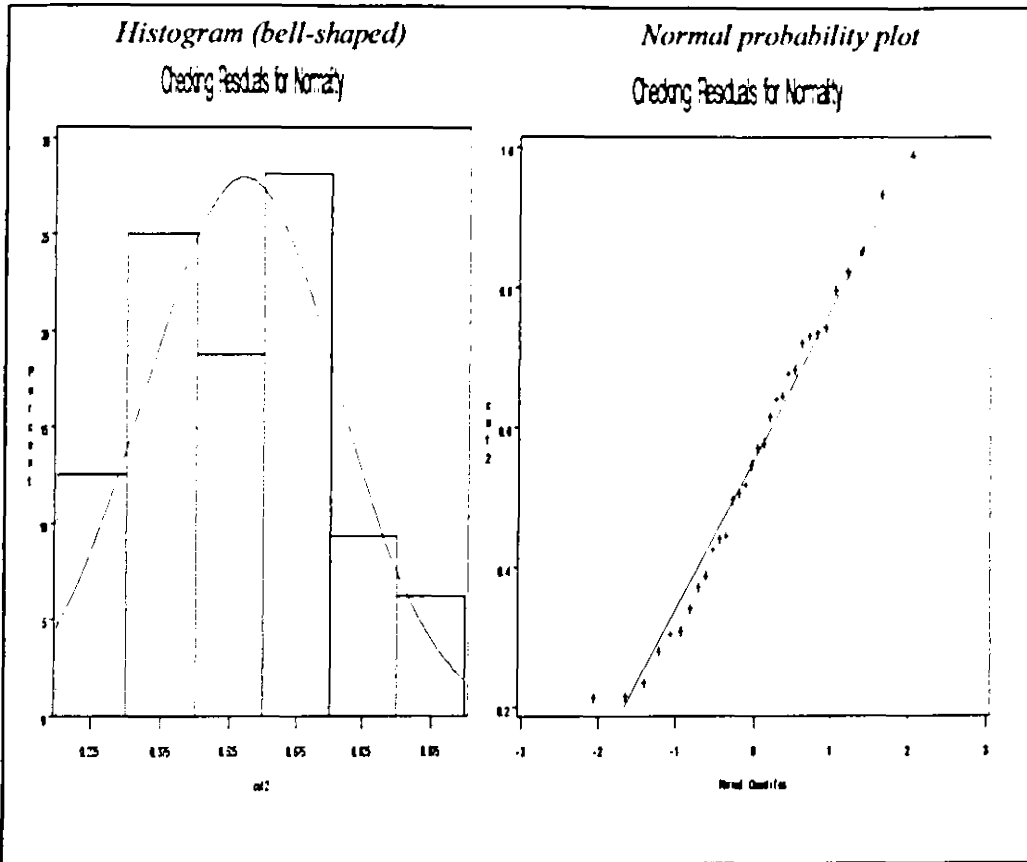
We hypothesize that our data follows a normal distribution, and only reject this hypothesis if we have evidence to the contrary. We now check the studentized residuals for normality, using Proc Univariate in SAS.

Figure 1: Testing for normality for the first Cut



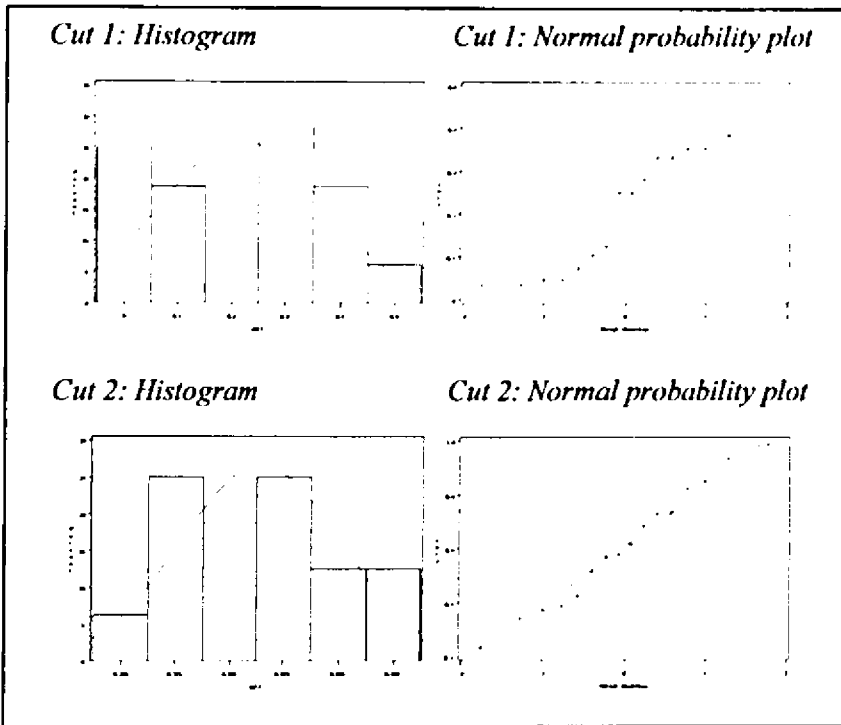
On the normal probability plot above (figure 1), data appear linear (a straight line) and data points fall close to the straight line. The residuals appear to be fairly normally distributed. The histogram doesn't look very normal.

Figure 2: Testing for normality for the Second Cut



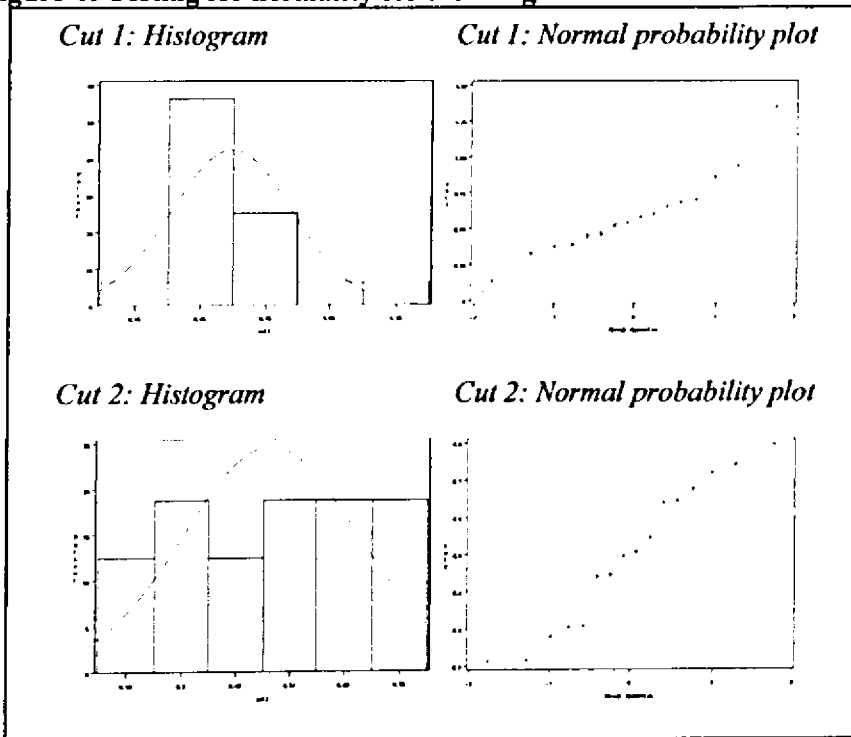
On the normal probability plot above (figure 2), data appear linear (a straight line) and data points fall close to the straight line. The residuals appear to be fairly normally distributed. The histogram appears bell-shaped showing the data is normally distributed.

Figure 3: Testing for normality for the Short rain season



The data for the two cuts in short rain appears to be fairly normally distributed (Figure 3).

Figure 4: Testing for normality for the Long rain season



The data for the two cuts in long rain season appears to be fairly normally distributed (*Figure 4*).

2.2. Testing data for Independence

2.2.1. Correlation

We now check the correlation between the two cuts DM yields to test independence.

Correlation between the two Cuts

Variable	N	Mean	SD	Sum	Minimum	Maximum
cut1	32	0.41	0.29	13.03	0.03	1.35
Cut2	32	0.55	0.21	17.74	0.21	0.99

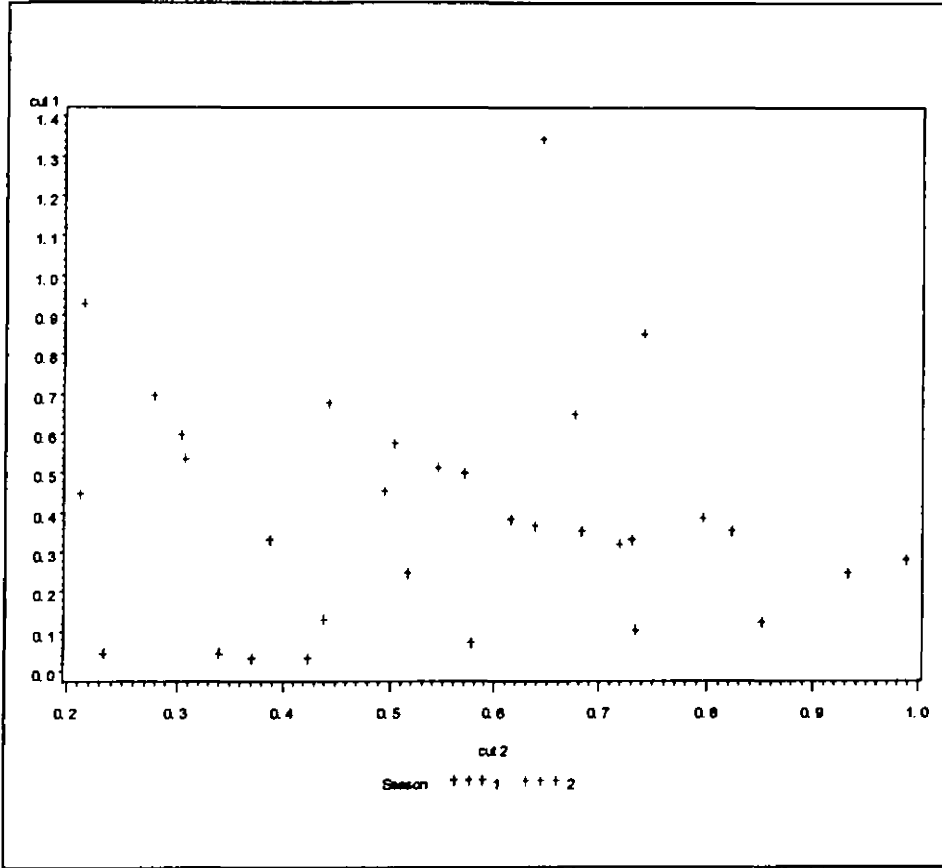
	Cut1	Cut 2
Cut 1	1.00000	-0.07888
Cut 1(P-value)		0.6678
Cut 2	-0.07888	1.00000
Cut 2(P-value)	0.6678	

The reported correlation measures show a (not significant, according to the p-value) negative correlation between Cut 1 and Cut 2.

2.2.2. Scatter Plot

To examine if there is any relationship between two fodder grass yields, we plot a scattergram.

Figure 5: Scatter plot of Cut 1 against Cut 2.



The Scatter plot shows no linear relationship between the two Cuts for the two seasons. Thus, the two cuts are independent.

2.3. Descriptive statistics

Table I: Means fodder DM yield (tones/ha) of four grass varieties at two different successful cuttings

Seasons	Grass Varieties	Cuttings	
		I	II
Short rain	Bana	2.97	9.34
	Cameroon	2.5	8.77
	Bajra	4.56	7.11
	P maximum	0.48	4.1
	Total mean	2.63	7.33
Long rain	Bana	8.04	3.03
	Cameroon	9.58	6.93
	Bajra	6.08	8.26
	P maximum	4.86	5.67
	Total mean	7.14	5.97

The data regarding to the mean dry matter fodder yield t/ha are presented in Table 2 above. The total mean yield of the four fodder varieties was high in long rain season (7.14 t/ha) compared to the total mean yield of the short season (2.63 t/ha) in the first cut. The mean yield of second cut during short rain season is higher (7.33 t/ha) compared to the mean yield of Long rain (5.97 t/ha).

CHAPTER 3

COMBINED ANALYSIS

3.0. Introduction

In an experiment we often examine which treatment is adapted to which kind of experiment. The analysis of variance over different seasons shows whether treatments effects changes under different normal conditions. It is necessary to repeat the trial of a set of experiments like fodder grass varieties at a number of places or in a number of seasons. The aim of repetitions is to study the susceptibility of treatment effects to place variations.

In combine analysis of data the main points of interest would be

- i. To estimate the average response to given treatment
- ii. To test consistency of the response from season to season i.e. Interaction of the treatment effect with seasons.

The results of a set of trial may, therefore be considered as belonging to one of the following four types:

- i. The experimental errors are homogeneous and the interaction is absent
- ii. The experimental errors are homogeneous and the interaction is present
- iii. The experimental errors are heterogeneous and the interaction is absent
- iv. The experimental errors are heterogeneous and the interaction is present

3.1. Analysis Procedures

For combined analysis for groups of experiments following steps are to be followed;

Step I: Construct an outline of combined analysis of variance over seasons.

Step II: Perform usual analysis of variance for the given data. In our study the experiment conducted is in randomized complete block design. Perform analysis of the two seasons separately.

Step III: We have p error mean, where p is the number of seasons and we have to test for homogeneity of variances. We have the following situations:

Situation I; When P=2

We apply F-test for testing the homogeneity of variance. Let Se_1^2 and Se_2^2 be the mean square errors (MSE) for the two seasons. The value of F statistics will be Se_1^2 / Se_2^2 and this value will be tested against the table F Value at n_1 and n_2 degrees of freedom at 5% level of significance, where n_1 and n_2 are degrees of freedom (df) of errors of the two seasons, respectively. If the calculated F is greater than tabulated F value then the null hypothesis of homogeneity of variance is rejected and the data is heterogeneous in different seasons, otherwise it is homogeneous. You put the larger variance on the numerator.

Situation II; When P>2

In this situation we apply Bartlett's Chi-Square. The null and alternative hypotheses are

$H_0: \sigma_1^2 = \sigma_2^2 = \dots = \sigma_p^2$ against the alternative hypothesis

H_1 : at least two of the σ_i^2 's are not equal where σ_i^2 are the error variance for i^{th} season.

Let $Se_1^2, Se_2^2, \dots, Se_p^2$ be the MSE of p seasons respectively and n_1, n_2, \dots, n_p are the df for the p locations. The statistics

$$\chi^2_{p-1} = \frac{\sum n_i \log Se_i^2 - \sum n_i \log Se^2}{1 + \frac{1}{3(p-1)} \left(\sum \frac{1}{n_i} - \frac{1}{\sum n_i} \right)}, \quad \text{where} \quad Se^2 = \frac{\sum n_i Se_i^2}{\sum n_i}$$

And if $n_i = n$

$$\chi^2_{p-1} = \frac{p[\log Se_c^2 - \sum \log Se_i^2]}{1 + \frac{(p+1)}{3np}}$$

Where χ^2_{p-1} follow χ^2 distribution with p-1 df. If the calculated value of χ^2_{p-1} is greater than tabulated χ^2_{p-1} value at p-1 df then the null hypothesis of homogeneity of variance is rejected the data is heterogeneous in different seasons, otherwise it is homogeneous.

Step IV: If error values are homogeneous, then for performing the combined analysis of weighted least square is required, the weight being the reciprocal of the root mean square. The weighted analysis is carried out by defining a new variable as newres=res/square root mean square. The new variable is thus homogeneous and thus combined analysis can be performed on this new variable. If error variances are homogeneous then there is no need to transform the data.

Step V: Now we view the groups of experiment as a nested design with several factors within one another. The seasons are treated as a big blocks, with the experiment nested within these. Next step in the analysis is to test from the significant of seasons X treatment interaction.

Combined analysis of variance follows the following statistical model;

$$Y_{ijkl} = \mu + S_i + B(S)_{j(i)} + T_k + (S \times T)_{ik} + e_{ijkl}$$

Where;

Y_{ijkl} = the observed values

μ = the general mean

S_i = Effect of the i^{th} season

$B(S)_{j(i)}$ = Effect of the j^{th} block within the i^{th} season

T_k = Effect of the k^{th} treatment

$(S \times T)_{ik}$ = Interaction effect between the i^{th} season and k^{th} treatment

e_{ijkl} = Random error

A general format for combined analysis over sites for an experiment carried out at s seasons with t test treatments replicated r times each season is given in the table II below

Table II: General format for combined analysis of variance over seasons

Source of variation	Df	SS	MS	F-value
Seasons(S)	$s-1$	SS_L	MS_L	
Reps within seasons	$s(b-1)$	SS_R	MS_R	
Treatments(T)	$t-1$	SS_t	MS_t	
Interaction(SxT)	$(s-1)(t-1)$	SS_I	MS_I	
Pooled Error	$s(b-1)(t-1)$	SS_E	MS_E	

To test for the presence of season main effect, compare MS_L to MSE ie to get the F-Value for testing season main effect divide MSE by MS_L . The test used for assessing the presence of treatment main effect depends on whether the seasons are fixed or a random sample. If the seasons are fixed, MST is compared to MSE , for random sample of sites MST is compared to MS_L . MS_L is compared to MSE for both fixed and random seasons. In our case seasons are fixed sample.

3.2. Data Analysis

3.2.1. Combine Analysis for Cut 1

First we analyze data for each season separately. We will get two ANOVA tables that give significance of treatments for two seasons separately. Further analysis (stability analysis) of this interaction can be performed.

Table III: Analysis of variance for Short rain season

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	38.45980000	6.40996667	5.02	0.0158
Error	9	11.48450000	1.27605558		
Corrected Total	15	49.94430000			

The error mean square is 1.28 with 9 degrees of freedom.

Table IV: Analysis of variance for Long rain Season

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	149.4266500	24.9044417	9.99	0.0015
Error	9	22.4343250	2.4927028		
Corrected Total	15	171.8609750			

The error mean square is 2.49 with 9 degrees of freedom.

Since the error mean square, $p=2$, we apply F-testing the homogeneity of variance.

We test hypothesis; $H_0: \sigma_1^2 = \sigma_2^2$ against $H1: \sigma_1^2 \neq \sigma_2^2$

F statistics will be;

$$Se_1^2 / Se_2^2 = 2.49 / 1.28 = 1.95$$

$$F_{value}(0, 95, 9, 9) = 3.18.$$

Since F statistic value is less than F- tabulated value, we do not reject the null hypothesis of homogeneity of variance and conclude that the two data sample come from the same population.

So we can perform combined analysis.

Table V: Combine Analysis of Variance for Cut 1

Source	DF	SS	Mean Square	F Value	Pr > F
Season	1	162.9915125	162.9915125	86.50	<.0001
rep(Season)	6	101.6445750	16.9407625	8.99	0.0001
treat	3	54.4224375	18.1408125	9.63	0.0005
Season*treat	3	31.8194375	10.6064792	5.63	0.0087

***** Significant at 0.05% level of probability**

All factors showed significant effect. A significant effect of seasons ($p < 0.0001$) implied that means of treatments varied considerably at different seasons. Significant effect of seasons x

treatment interaction ($p=0.0067$) means that a number of fodder grass varieties produced higher dry matter yield in one of the season.

3.2.2. Combine Analysis of variance for Cut 2

Table VI: Analysis of variance for Short rain Season

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	73.8909000	12.3151500	3.20	0.0573
Error	9	34.5923000	3.8435889		
Corrected Total	15	108.4832000			

The error mean square is 3.84 with 9 degrees of freedom.

Table VII: Analysis of variance for Long rain Season

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	6	71.01530000	11.83588333	10.66	0.0012
Error	9	9.99160000	1.11017778		
Corrected Total	15	81.00690000			

The error mean square is 1.11 with 9 df.

Since the error mean square, $p=2$, we apply F-testing the homogeneity of variance.

We test hypothesis; $H_0: \sigma_1^2 = \sigma_2^2$ against $H_1: \sigma_1^2 \neq \sigma_2^2$

F statistics will be;

$$Se_1^2 / Se_2^2 = 3.84 / 1.11 = 3.45$$

F value (0, 95, 9, 9) = 3.18.

Since F statistic value is greater than F- tabulated value, we reject the null hypothesis of homogeneity of variance and conclude that the two data sample do not come from the same population. We fail to perform combine analysis.

Table VIII: Combine Analysis of Variance for Cut 2

Source	DF	SS	Mean Square	F Value	Pr > F
Season	1	29.72205000	29.72205000	29.73	<.0001
rep(Season)	6	12.32005000	2.05334167	2.05	0.1107
treat	3	27.60947500	9.20315833	9.21	0.0007
Season*treat	3	43.32667500	14.44222500	14.45	<.0001

A significant effect of seasons ($p < 0.0001$) implied that means of treatments varied considerably at different seasons for cut 2.

3.2.3. Combine Analysis for Totals

Table IX: Analysis of variance for Short rain Season

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	168.0290500	20.0048417	6.06	0.0153
Error	9	49.6134500	5.5126056		
Corrected Total	15	217.6425000			

The error mean square is 5.51 with 9 df.

Table X: Analysis of variance for Long rain Season

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	200.8916000	33.4819333	6.47	0.0070
Error	9	46.5715750	5.1746194		
Corrected Total	15	247.4631750			

The error mean square is 5.51 with 9 df.

We test hypothesis; $H_0: \sigma_1^2 = \sigma_2^2$ against $H_1: \sigma_1^2 \neq \sigma_2^2$

F statistics will be;

$$S_{e1}^2 / S_{e2}^2 = 5.51 / 5.17 = 1.07$$

F value (0, 95, 9, 9) = 3.18.

Since F statistic value is less than F- tabulated value, we do not reject the null hypothesis of homogeneity of variance and conclude that the two data sample come from the same population.

So we can perform combined analysis.

Table XI: Combine Analysis of Variance for totals

Source	DF	SS	Mean Square	F Value	Pr > F
Season	1	79.6953125	79.6953125	14.91	0.0011
rep(Season)	6	117.4824250	19.5804042	3.66	0.0148
treat	3	188.1112625	62.7037542	11.73	0.0002
Season*treat	3	63.3269625	21.1089875	3.95	0.0251

*** Significant at 0.05% level of probability

All factors showed significant effects. Season*treatment were significant [$F(3, 15) = 3.95$, $P=0.0251$] indicating that some fodder grass produced higher dry matter yield in one of the season after combining the two cuts.

Since interaction is significant for the two cuts, we carry out the stability analysis.

CHAPTER 4

STABILITY ANALYSIS

4.0. Introduction

When varieties are tested over a number of seasons, the relative ranking of these varieties may vary from one season to the other, and it become difficult to demonstrate which variety is superior. We will illustrate the application of the statistical method by Hilderbrand and Eberhart and Rusell to estimate variety stability.

The yield of each variety can be related to season by a simple linear regression.

$$Y_{ij} = a + bX_i$$

Where;

Y_{ij} = Yield of the i^{th} variety at the j^{th} season.

X_i = Mean of the variety yields per season

By fitting the regression equation independently for each variety, then plotting the yield response to the season for each variety on the same graph, we can visually compare varieties.

A variety with unit coefficient ($b=1$) is said to be stable. We are interested in testing the following null and alternative hypothesis;

$H_0: b=1$; against $H_a: b \neq 1$.

We calculate the value of $t = \frac{b-1}{S.E(b)}$

Where b = variety unit coefficient.

S.E (b) = standard error of variety unit coefficient.

4.1. Stability analysis for Cut 1

We fit regression for each variety. A variety with unit coefficient ($b=1$) is said to be stable. We are interested in testing the following null and alternative hypothesis;

$H_0: b=1$; against $H_a: b \neq 1$.

We calculate the value of $t = \frac{b-1}{S.E(b)}$

Where b = variety unit coefficient.

S.E (b) = standard error of variety unit coefficient.

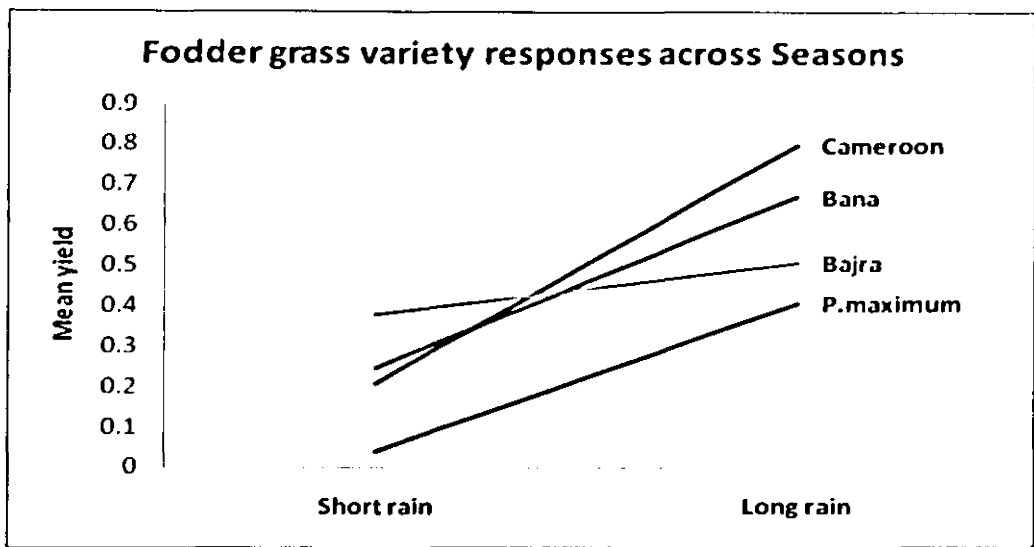
Table XII: Parameter estimates for the first cut

	parameter estimate(b)	SE(b)	b-1	t-value
Bana	1.125	0.319	0.125	0.392
Cameroon	1.570	0.518	0.570	1.100
Bajra	0.336	0.334	-0.664	1.988
P.maximum	0.972	0.270	-0.028	0.103

At the 5% level of significant and 6 degrees of freedom, the tabular t is 2.45, the absolute values of the calculated t are less than the tabular t . Therefore regression coefficients are not significant different from 1. Thus, we conclude varieties are stable over the seasons for the first cut.

Using the fitted regression equations, the yield response to season for each variety is plotted on the same graph (figure 6)

Figure 6: fodder grass varieties responses across seasons



From the figure 6 above, a visual comparison shows that all the four varieties have similar responses to the seasons.

4.2. Stability analysis for Cut 2

We fit regression for each variety independently for cut 2. A variety with unit coefficient ($b=1$) is said to be stable. We are interested in testing the following null and alternative hypothesis;

$H_0: b=1$; against $H_a: b \neq 1$.

We calculate the value of $t = \frac{b-1}{S.E(b)}$

Where b = variety unit coefficient.

S.E (b) = standard error of variety unit coefficient.

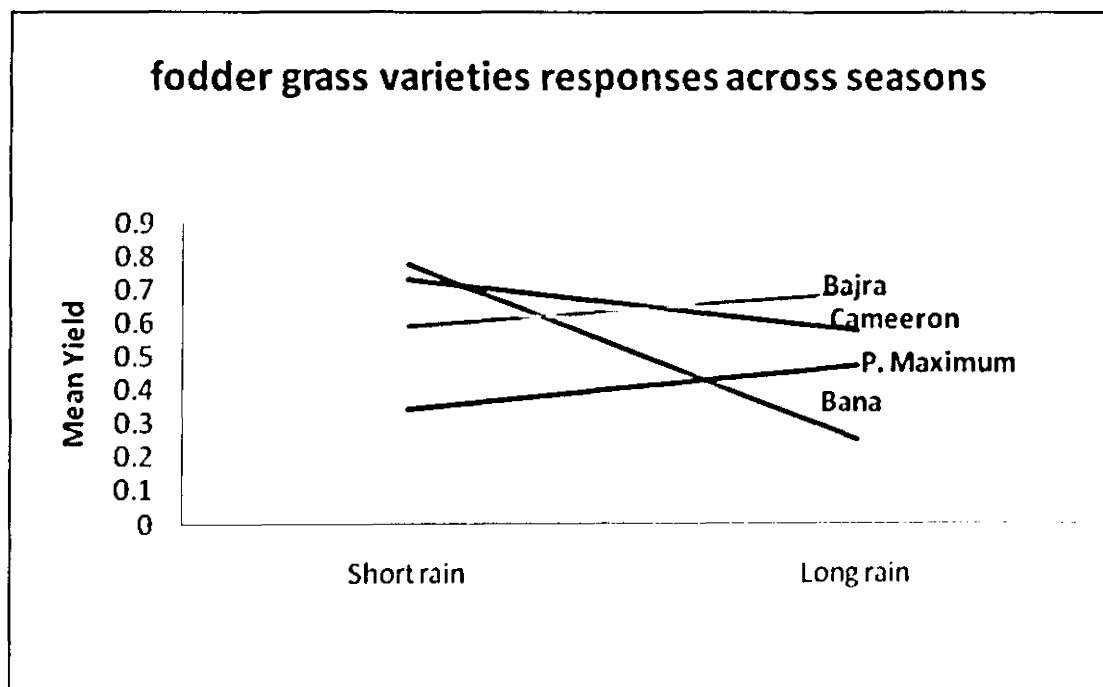
Table XIII: Parameter estimates for the second cut

Variable	Df	parameter estimate(b)	SE(b)	b-1	t-value
Bana	1	14.02	2.90	13.02	4.49
Cameroon	1	4.09	2.46	3.09	1.26
Bajra	1	-2.56	2.70	-3.56	1.32
P.Maximum	1	-11.54	1.84	-12.54	6.81

At the 5% level of significant and 6 degrees of freedom, the tabular t is 2.45, the absolute values of the calculated t are greater than the tabular t. Therefore regression coefficients are significant different from 1. Thus, we conclude varieties are not stable over the seasons for the second cut.

Using the fitted regression equations, the yield response to season for each variety is plotted on the same graph (figure 7)

Figure 7: fodder grass varieties responses across seasons



From the figure 7 above, a visual comparison shows that all the four varieties do not have similar responses to the seasons.

CHAPTER 5

COMBINED ANALYSIS FOR REPEATED MEASURES

5.0. Introduction

The analysis of repeated measurements experiments is a powerful experimental test procedure in the field of agricultural, biological and clinical research (Rahman, 1989; Madsen, 1977; Lana & Lubin, 1963). A repeated measure is a variable measured two or more times, usually before, during and/or after an intervention or treatment.

When several measurements are taken on the same experimental unit (e.g. person, animal, machine), the measurements tend to be correlated with each other. When the measurements represent qualitatively different things, such as yield, weight, length, and width, this correlation is best taken into account by use of multivariate methods, such as multivariate analysis of variance. When the measurements are responses to levels of an experimental factor of interest, such as time, treatment, or dose, the correlation can be taken into account by performing a repeated measures analysis of variance. A popular repeated-measures design is the crossover study. A crossover study is a longitudinal study in which subjects receive a sequence of different treatments (or exposures). Repeated measures allow conducting an experiment when few participants are available. The repeated measure design reduces the variance of estimates of treatment-effects, allowing statistical inference to be made with fewer subjects. A repeated measure allows conducting experiment more efficiently.

5.1. When to use repeated measures

Repeated measure tests the equality of means. However, a repeated measure MANOVA is used when all members of a random sample are measured under a number of different conditions. As the sample is exposed to each condition in turn, the measurement of the dependent variable is

repeated. Using a standard MANOVA in this case could not be appropriate because it fails to model the correlation between the repeated measures. The data violate the MANOVA assumption of independence. If any repeated factor is present, then repeated measures MANOVA should be used.

This approach is used for several reasons. First, some research hypotheses require repeated measures. Longitudinal research, for example, measures each sample member at each of several ages. In this case, age would be a repeated factor. Second, in cases where there is a great deal of variation between sample members, error variance estimates from standard MANOVAs are large. Repeated measures of each sample member provide a way of accounting for this variance, thus reducing error variance. Third, when sample members are difficult to recruit, repeated measures designs are economical because each member is measured under all conditions.

One should be clear about the difference between a repeated measures design and a simple multivariate design. For both, sample members are measured on several occasions, or trials, but in the repeated measures design, each trial represents the measurement of the same characteristic under a different condition.

5.2. Analysis of repeated measure General Model

One approach to analyze fodder grass trial data is to fit a multivariate repeated measures generalized linear model with PROC GLM in SAS. Two responses, cut1 and cut2 are each measured (replicated) two times for each season. Each season had four treatments. The repeated measures analysis includes multivariate tests for seasons and treatment main effects, as well as their interactions, across responses.

The required repeated measurements model can be expressed as;

$$Y_{ijkl} = \mu + S_i + B(S)_{j(i)} + T_k + (S \times T)_{ik} + e_{ijkl}$$

Where;

Y_{ijkl} = the observed values

μ = the general mean

S_i = Effect of the i^{th} season

$B(S)_{j(i)}$ = Effect of the j^{th} block within the i^{th} season

T_k = Effect of the k^{th} treatment

$(S \times T)_{ik}$ = Interaction effect between the i^{th} season and k^{th} treatment

e_{ijkl} = Random error

Assumptions;

1. $e_{ijkl} = N(0, \sigma^2_{\epsilon})$
2. All the variances in the different seasons are equal
 $\sigma_1^2 = \sigma_2^2$

The following Hypothesis are to be tested:

1. $H_0(\text{treatment})$: the treatment effect are equal
2. $H_0(\text{Season})$: the seasons effect are equal
3. $H_0(\text{treatment x Season})$: the treatment x season interaction are nil

These hypotheses about the main effect and the interaction can be tested using F-statistics with respective degrees of freedom.

5.2.1. Hypothesis Testing in MANOVA

All current MANOVA tests are made on $A = E^{-1}H$. That's the good news. The bad news is that there are four different multivariate tests that are made on $E^{-1}H$. Each of the four test statistics has its own associated F ratio. In some cases the four tests give an exact F ratio for testing the null hypothesis and in other cases the F ratio is approximated.

The reason for four different statistics and for approximations is that the mathematics of MANOVA get so complicated in some cases that no one has ever been able to solve them. (Technically, the math folks can't figure out the sampling distribution of the F-statistic in some multivariate cases.). To understand MANOVA, it is not necessary to understand the derivation of the statistics. Here, all that is mentioned is their names and some properties. In terms of notation, assume that there are q dependent variables in the MANOVA, and let λ_i denote the i^{th} eigenvalue of matrix A which, of course, equals HE^{-1} .

The first statistic is *Pillai's trace*. Some statisticians consider it to be the most powerful and most robust of the four statistics. The formula is

$$\text{Pillai's trace} = \text{trace} [H (H + E)^{-1}] = \sum_{i=1}^q \frac{\lambda_i}{1 + \lambda_i}$$

The second test statistic is *Hotelling-Lawley trace*.

$$\text{Hotelling-Lawley's trace} = \text{trace} (A) = \text{trace} (HE^{-1}) = \sum_{i=1}^q \lambda_i$$

The third is *Wilk's lambda* (L). (Here, the upper case, Greek L is used for Wilk's lambda to avoid confusion with the lower case, Greek λ often used to denote an eigenvalue. However, many texts use the lower case lambda as the notation for Wilk's lambda.)

Wilk's L was the first MANOVA test statistic developed and is very important for several multivariate procedures in addition to MANOVA.

$$\text{Wilk's lambda} = \frac{|E|}{|H + E|} = \prod_{i=1}^q \frac{1}{1 + \lambda_i}$$

The quantity $(1 - \hat{\lambda})$ is often interpreted as the proportion of variance in the dependent variables explained by the model effect. However, this quantity is not unbiased and can be quite misleading in small samples.

The *wilk's* test is commonly used. *Wilks' lambda* is a test statistic used in multivariate analysis of variance (MANOVA) to test whether there are differences between the means of identified groups of subjects on a combination of dependent variables.

The null hypothesis is that mean fodder grass yield does not change across different cuts.

Table XIV: Manova Test Criteria and Exact F Statistics for the Hypothesis of no cuts Effect

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.37842583	29.57	1	18	<.0001
Pillai's Trace	0.62157417	29.57	1	18	<.0001
Hotelling-Lawley Trace	1.64252572	29.57	1	18	<.0001
Roy's Greatest Root	1.64252572	29.57	1	18	<.0001

Since the F value for this hypothesis is large [$F(1, 18) = 29.57, p < 0.0001$], we reject the null hypothesis and conclude that the mean yield of fodder grasses change across different cuts.

Next we test the hypothesis that Season will interact with the cuts.

Table XV: Manova Test Criteria and Exact F Statistics for the Hypothesis of no cuts*Season Effect

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.18069425	81.62	1	18	<.0001
Pillai's Trace	0.81930575	81.62	1	18	<.0001
Hotelling-Lawley Trace	4.53421055	81.62	1	18	<.0001
Roy's Greatest Root	4.53421055	81.62	1	18	<.0001

In this instance, the F value associated with these multivariate tests if the interaction is high [$F(1, 18) = 81.62, p < 0.0001$], therefore we reject the null hypothesis and conclude that change in mean yield for the two cuts depend upon the season.

Next we test the null hypothesis that Treatments (fodder grass varieties) will not interact with the cuts to produce different mean yield.

Table XVI: Manova Test Criteria and Exact F Statistics for the Hypothesis of no cuts x treatment (fodder grass yield) Effect

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.81353050	1.38	3	18	0.2823
Pillai's Trace	0.18646950	1.38	3	18	0.2823
Hotelling-Lawley Trace	0.22921021	1.38	3	18	0.2823
Roy's Greatest Root	0.22921021	1.38	3	18	0.2823

By examining the Wilks' lambda value (0.81), associated F value and p value [$F(3, 18) = 1.38, p < 0.2823$], we conclude that any mean differences between the two cuts do not depend on the type of fodder grass variety.

We now test the null hypothesis of no season x Treatment by cut interaction

Table XVII: Manova Test Criteria and Exact F Statistics for the Hypothesis of no cut x season x treatment

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.27715404	15.65	3	18	<.0001
Pillai's Trace	0.72284596	15.65	3	18	<.0001
Hotelling-Lawley Trace	2.60810184	15.65	3	18	<.0001
Roy's Greatest Root	2.60810184	15.65	3	18	<.0001

By examining the F-value associated with the wilks' Lambda test [$F(3, 18) = 15.65, P < 0.0001$],

we reject null hypothesis conclude there is interaction among season, treatment and cut.

Following the multivariate tests of significance for within-subjects effects, we test the hypothesis for between-subjects effects.

Table XVIII: Univariate Tests of Hypotheses for Within Subject

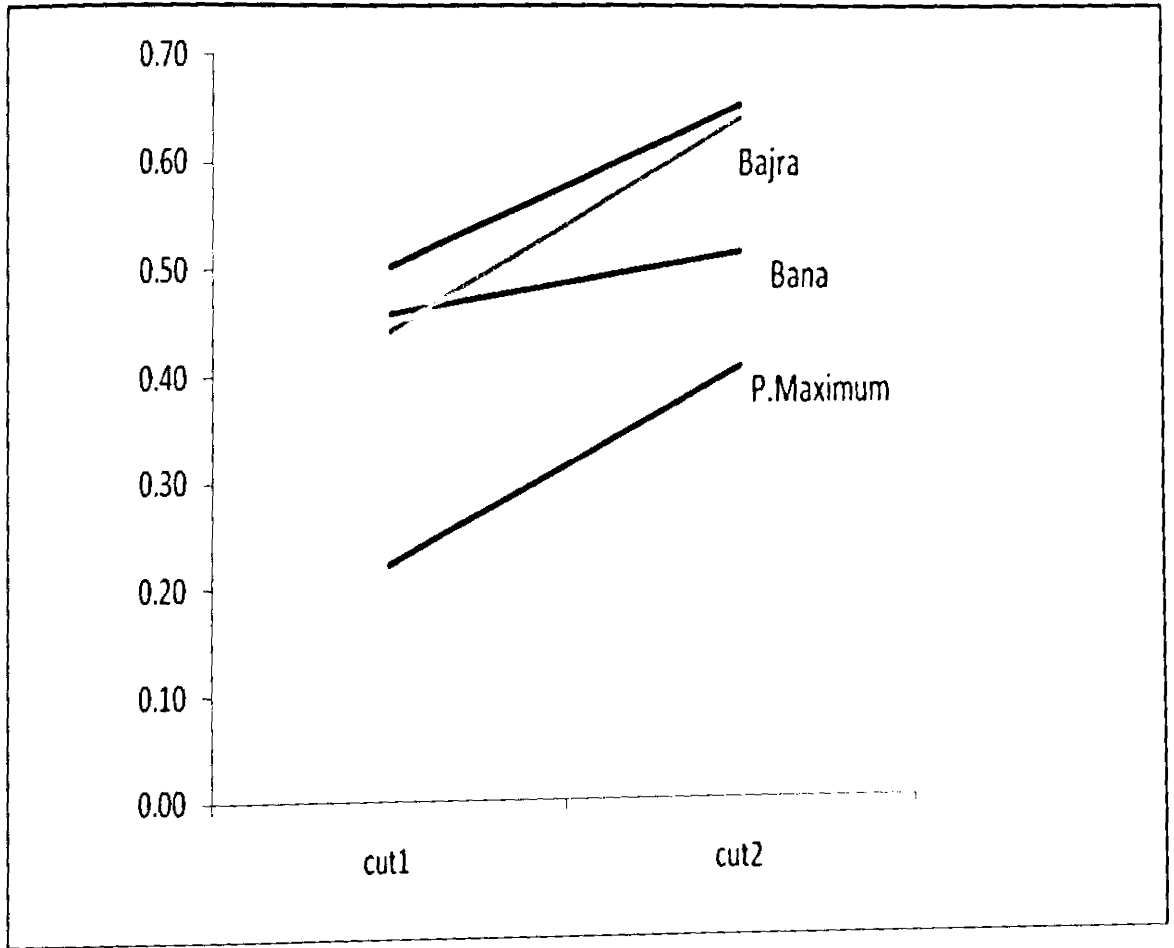
Source	DF	SS	Mean Square	F Value	Pr > F
CUT	1	49.9495563	49.9495563	29.57	<.0001
CUT*Season	1	137.8863063	137.8863063	81.62	<.0001
CUT*rep(Season)	6	62.0490625	10.3415104	6.12	0.0012
CUT*treat	3	6.9703313	2.3234438	1.38	0.2823
CUT*Season*treat	3	79.3129312	26.4376437	16.65	<.0001
Error(CUT)	18	30.4102125	1.6894563		

Looking at season main effect, with the P value < 0.001, we have statistically significance effect.

We therefore conclude that a statistical difference exists between seasons on their overall mean yields. The test of season x treatment interaction also shows significant results [$F(1, 18) = 15.65, p < 0.0001$]. This suggests that seasons and fodder grass variety combine to influence of the overall mean of the yield.

Finally, we plot the mean yields of the four fodder variety to see the responses across the two cuts.

Figure 8: fodder grass varieties responses across the two Cuts



From the figure 8 above, a visual comparison shows that all the four varieties have similar responses to the two different cuts.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The total mean yield of the four fodder varieties was high in long rain season (7.14 t/ha) compared to the total mean yield of the short season (2.63 t/ha) for the first cut. The mean yield of second cut during short rain season was higher (7.33 t/ha) compared to the mean yield of Long rain (5.97 t/ha). Season had significant effect on the yield ($p=0.0067$ for cut 1 and $p<0.0001$ for cut 2) of fodder grass variety. This is in agreement with Anindo & Potter (1994) who indicated that seasonal variation could cause drastic changes in fodder yields. The significant reduction in yield during the short rain season could be due to inadequate moisture causing reduction in vegetative growth.

Examining the effect of seasons and treatments interaction of the two harvests (cut 1 and cut 2), showed significance ($p=0.0067$ and $p<0.001$) respectively) meaning that a number of fodder grass varieties produced higher dry matter yield in one of the season than the other. By plotting the cells means of the four varieties, we realize that mean DM yields increases across seasons for the first cut. But results are different for the second cut where Bana and Cameroon DM yield was low during long rainfall seasons.

There is evidence of yields different between the two cuts [$F(1, 18) = 29.57, p < 0.0001$]. Mean yield of P. Maximum grass was higher during the second cut for the two seasons. This is contrary to the findings of V. A. Oyenukar who studied the effect of stage of growth and frequency of cutting on the yield and chemical composition of *Panicum maximum* and found that yields of dry matter and of green fodder reduces with successive cuttings.

In conclusions, the results of this study indicate that harvest management of fodder grass varies according to season. There is need of farmers in Kenya to beef up moisture requirement during short rain season to have adequate surplus of fodder crop throughout the year.

APPENDICES

I. Fodder grass data

Season	treatment	replications	cut1	cut2	total
1	1	1	4.62	7.38	12
1	2	1	1.25	8.81	10.06
1	3	1	6	6.84	12.84
1	4	1	0.41	4.45	4.86
1	1	2	3.38	11.86	15.24
1	2	2	4.25	9.87	14.12
1	3	2	4	8.76	12.76
1	4	2	0.55	2.8	3.35
1	1	3	3	11.19	14.19
1	2	3	3	6.19	9.19
1	3	3	4	4.64	8.64
1	4	3	0.55	4.08	4.63
1	1	4	0.87	6.92	7.79
1	2	4	1.5	10.21	11.71
1	3	4	4.25	8.19	12.44
1	4	4	0.41	5.09	5.5
2	1	1	7.19	3.64	10.83
2	2	1	6.21	6.55	12.76
2	3	1	4.68	9.55	14.23
2	4	1	4.43	7.67	12.1
2	1	2	5.41	2.55	7.96
2	2	2	7.8	8.11	15.91
2	3	2	3.89	8.64	12.53
2	4	2	1.6	5.28	6.88
2	1	3	8.4	3.35	11.75
2	2	3	8.16	5.33	13.49
2	3	3	5.49	5.94	11.43
2	4	3	6.48	3.69	10.17
2	1	4	11.17	2.58	13.75
2	2	4	16.15	7.73	23.88
2	3	4	10.25	8.9	19.15
2	4	4	6.95	6.05	13

II. SAS Syntax

i. Import data from Excel

```
PROC IMPORT OUT= WORK.reuben  
DATAFILE= "C:\Users\Reuben.ngumo\Desktop\My Document\New project\data_final"  
DBMS=EXCEL2000 REPLACE;  
GETNAMES=YES;  
RUN;
```

ii. Testing normality (Histogram and Normal probability plot)

```
/*Cut 1*/
```

```
proc univariate data=Reuben PLOT NORMAL;  
var cut1;  
histogram / normal;  
qqplot / normal(mu=est sigma=est);  
run;
```

```
/*Cut 2*/
```

```
proc univariate data=Reuben PLOT NORMAL;  
var cut2;  
histogram / normal;  
qqplot / normal(mu=est sigma=est);  
run;
```

```
/*Short rain season*/
```

```
DATA Reuben; SET Reuben;  
IF (Season=1);  
run;
```

```
proc univariate data=Reuben PLOT NORMAL;  
var cut1;  
histogram / normal;  
qqplot / normal(mu=est sigma=est);  
run;
```

```
/*Long rain season*/
```

```
DATA Reuben; SET Reuben;  
IF (Season=2);  
run;
```

```
proc univariate data=Reuben PLOT NORMAL;  
var cut2;  
histogram / normal;  
qqplot / normal(mu=est sigma=est);  
run;
```

iii. Check for independence

/*Correlation of the two cuts*/

```
proc corr data=Reuben;
var cut1 cut2;
run;
```

/*Scatter Plot*/

```
PROC GPLOT DATA=reuben;
PLOT cut1*cut2=Season;
RUN;
```

iv. Analysis of variance for the two seasons

/*Short rain*/

```
DATA Reuben; SET Reuben;
IF (Season=1);
run;
```

```
PROC GLM;
CLASS rep treat;
MODEL cut1=rep treat/ss3;
RUN;
```

/*Long rain*/

```
DATA Reuben; SET Reuben;
IF (Season=2);
run;
```

```
PROC GLM;
CLASS rep treat;
MODEL cut2=rep treat/ss3;
RUN;
```

V. Combined Analysis of variance

```
/*Cut 1*/
CLASS Season rep treat;
MODEL cut1 =Season rep (Season) treat Season*treat/ nouni;
RUN;
```

```
/*Cut 2*/
CLASS Season rep treat;
MODEL cut2 =Season rep (Season) treat Season*treat/ nouni;
RUN;
```


vi. Estimation of Parameters for stability analysis

```
/*Bana grass*/  
DATA Reuben; SET Reuben;  
IF (treat=1);  
run;  
PROC REG DATA=dummy2;  
MODEL cut1 = mean;  
RUN;
```

```
/*Cameroon grass*/  
DATA Reuben; SET Reuben;  
IF (treat=2);  
run;  
PROC REG DATA=dummy2;  
MODEL cut1 = mean;  
RUN;
```

```
/*Bajra grass*/  
DATA Reuben; SET Reuben;  
IF (treat=3);  
run;  
PROC REG DATA=dummy2;  
MODEL cut1 = mean;  
RUN;
```

```
/*P.Maximum grass*/  
DATA Reuben; SET Reuben;  
IF (treat=4);  
run;  
PROC REG DATA=dummy2;  
MODEL cut1 = mean;  
RUN;
```

vii. Combined analysis for repeated measures

```
PROC GLM;  
CLASS Season rep treat;  
MODEL cut1 cut2=Season rep (Season) treat Season*treat/ nouni;  
REPEATED TIME;  
LSMEANS treat/PDIFF STDERR;  
RUN;
```

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