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THE EFFECT OF PLANTING DEPTH ON THE PERFORMANCE OF THE IRISH POTATO (*Solanum tuberosum* L.) VARIETY LARNOMA IN NYANGA DISTRICT

BY

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Abstract

The Irish Potato (*Solanum tuberosum* L.) is an important tuber crop on a global scale. In Zimbabwe potato ranks the third after maize and wheat and worldwide it is ranked the fourth after maize, wheat and rice. Potato is crucially important to food security in Zimbabwe. The Nyanga highlands are one of the production hubs for Irish potatoes in Zimbabwe but it has been noted that there has been a marked decline in potato yields over the years. The decline in yields is attributable to several factors with agronomic, pests and diseases and general climate change. Among the agronomic factors, the planting depth is a crucial factor in potato production but there is no tested and proven planting depth for the Nyanga area. The study aimed at determining the proper planting depth for Irish Potato variety Larnoma. The study was undertaken at two sites namely; Nyamurindi farm and Muozi farm in the 2019-2020 cropping season. Four planting depths of 5 cm, 10 cm, 15 cm and 20 cm were used. The trial was laid out in a Randomised Complete Block Design with field slope as the blocking factor. Parameters measured include average tuber weights per plot for large, medium and small sized tubers, average number of tubers per plot for large, medium and small sized tubers, average number of branches per plant, average stem length, percentage emergence, percentage flowering and the percentage of mature foliage at selected intervals until harvest. The data was subjected to Analysis of Variance using MINITAB version16 statistical package. The 5 cm and 10 cm depths had significantly higher rates of emergence compared to the 15 cm and 20 cm depths. The planting depth of 10 cm was noted to be the most suitable in the production of the tubers with the biggest proportion of heavy tubers and the biggest number of tubers per plot. The 5 cm depth and 10 cm depth had significantly earlier emergence and earlier flowering compared to the 15 cm and 20 cm depths. The size of potato tubers is an important quality criterion and it is affected by the planting depth. In this study it was noted that the 10 cm planting depth produced the largest proportion of large sized tubers at both Nyamurindi and Muozi farms. It is recommended that further studies be done in areas which are different from these two for another season in order to validate these results.

Key Words: *Solanum tuberosum*, planting depth, Nyanga district

Declaration Page

I declare that this dissertation is my original work except where sources have been cited and acknowledged. The work has never been submitted nor will it ever been submitted to another University for the award of a degree.

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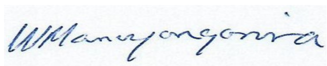
Walter Manyangarirwa __  __25/04/21

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Dedication

To the memory of my late father and mother John and Netty who strived so much to have me educated despite the hardships they faced.

List of Acronyms and Abbreviations

ANB	Average Number of Branches
ASL	Average Stem Length
FAO	Food and Agriculture Organization of the United Nations
GoZ	Government of Zimbabwe
LAN/MAN/SAN	Large Average Number/ Medium Average number/Small Average Number
LAwt/MAwt/SAwt	Large Average Weight/Medium Average weight/Small Average Weight
NPK	Nitrogen, Phosphorus and Potash
RCBD	Randomised Complete Block Design
%E	Percentage Emergence
%F	Percentage Flowering

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CHAPTER 1 INTRODUCTION

1.0 Introduction

The Irish potato (*Solanum tuberosum* L.) is a starchy tuberous crop that belongs to the solanaceae family, genus *Solanum* which is native to South America in the Andes region (Geraldine, 2006; Manzira & Ackerman, 2011; Graham, van de Fliert & Compilan, 2001). In Zimbabwe potato production is very prominent in Nyanga district (Figure 1) and it ranks the third after maize and wheat in terms of starch provision in Zimbabwe. Worldwide potato is ranked fourth after maize, wheat and rice in terms of starch provision and usage by the global population (FAO 2007, Graham *et al*., 2001). The Irish potato has several uses and is prepared as chips, mixed with meat, brewed as an alcoholic beverage, is used for medicinal purposes or being boiled with their skin or peeled whole in several dishes (Steyn, 2012). In Europe potato is treated as a staple crop and is ranked the first followed by rice and wheat (FAO, 2009). One of the major challenges facing potato production is to meet the increasing demand for the produce, particularly as populations increase in most parts of the world (Steyn, 2012). Potato tuber yield is improved by choosing the appropriate varieties and following proper agronomic practices (Manzira & Ackerman, 2011). The agronomic practices include proper soil tilth, proper weed control, pest control, proper plant spacing, proper varietal selection, proper soil fertility management and a uniform planting depth among others (Baarveld *et al*., 2002). Planting depth may be one of the most important practices that may address the problem of declining yields on Irish Potatoes in Zimbabwe (Manzira & Ackerman, 2011). From research done, shallow planting may be ideal in heavy soils and in light sand soils shallow planting may hasten emergence (Love, Eberlein, Stark

& Bohl, 1995). Some researchers have noted that shallow planting may produce small to medium sized tubers which are less preferred on the table potato market (Manzira & Ackerman, 2011). Shallow planting may be preferred in wet and heavy soils because deep planting in such soils may lead to exhaustion of stored food before sprouts emerge. In light soils shallow planting may lead to dehydration of tubers due to moisture stress as the tubers will be close to the soil surface (More, 2007). In light of these permutations on the selection of a proper planting depth for potatoes, it is important that research be conducted in the Nyanga area in order to address this question of a proper planting depth of potatoes for the ultimate benefit for the farmers.

1.1 Background to the Study

Potato is grown throughout the year in areas which are not prone to frost. Tuber yield can be improved by choosing appropriate varieties and more rational cultivation techniques. Tubers should be distributed evenly with a specific spacing between rows and uniform planting depth (Baarveld *et al*., 2002). Shallow planting depth is preferred in wet heavy soils because deep planted tubers may lead to exhaustion stored food before sprouts occur. Deep planting has the advantage of reducing dehydration of tubers due to moisture stress and less damage by pests (Lambion *et al*., 2006).

According to Gopal *et al*., (2002) stolons which develop into potato tubers emerge from the stem of the plant so the longer the stem underground the more the roots are going to develop. Within the potato production industry, there are no suitable guides on the appropriate planting depth that farmers can adopt in different areas. For this reason, among others, many farmers have resorted to the use of different planting depths resulting in potato yield distortions.

Figure1. Potatoes in Nyanga District at Brackenhills farm

1.3 Statement of the Problem

There is a significant problem of reduced yield due to differences in planting depths yet it is known that the longer the underground stem the more the roots are going to develop from the stems so it is ideal to determine the optimum number of tubers per stem from a deeper depth. Therefore it is ideal to come up with an optimum planting depth which gives optimum number of saleable tubers per plant. Identifying the proper planting depth in combination with hill shape, row width and other cultural management practices will become increasingly important in potato production (Pavek & Thorthon, 2009). Hilling provides a good cover for the newly formed tubers and to ensure that the developing tubers are covered with an adequate layer of soil. It is important to determine how planting depth up affects the growth and yield of potato. The pattern of stolon formation i.e. number and size of stolons, and the structure of the stolon system, can be influenced by cultural practices for example planting depth and build-up of the ridges (Darwin, 1991). Therefore, this study sought to address effect of planting depth on potato variety Larnoma yield and yield components in order to generate data that can be used by farmers and extension agents.

1.4 Research Objectives

1.4.1 Major Objective

To evaluate the effect of planting depth on the performance of the potato variety Larnoma in the high attitude potato growing area of Nyanga district.

1.4.2 Specific Objectives

The specific objectives of the study were to;

i) Determine the effect of planting depth on the emergence percentage of the potato variety Larnoma.

ii) Determine the effect of planting depth on tuber size of the potato variety Larnoma.

iii) Determine the effect of planting depth on tuber weight of the potato variety Larnoma

iv) Determine the effect of planting depth on the time to maturity for the potato variety Larnoma.

1.5 Research Questions

i) What is the effect of planting depth on emergence percentage for the potato variety Larnoma?

ii) What is the effect of planting depth on the tuber size for the potato variety Larnoma?

iii) What is the effect of planting depth on the tuber weight for the potato variety Larnoma?

iv) What is the effect of planting depth on the time to maturity for the potato variety Larnoma?

1.6 Significance of the Study

In the year 2000, the Government of Zimbabwe (GoZ), introduced the land reform programme throughout the country with the aim of equitably distributing land, correcting the historical land ownership imbalances to the majority of the population. In the Nyanga area, several new farmers received pieces of land and they moved into the production of Irish potato on a full scale. Irish Potato (*Solanum tuberosum* L.) is a high input cost crop according to potato handbook (2009) which needs its optimum yield to be ascertained to break even. Results from this study will be a huge stepping stone for farmers, particularly the new farmers who still lack knowledge on the proper planting depth for Irish potatoes. It is also known that the phenomenon of climate change has brought about changes that affect the physiology of several crops including potatoes. Results from this study will serve as an update on the research data that has been available to farmers. In other words, new research ideas are needed to address today's challenges that potato growers are facing.

1.7 Delimitation of the Study

The study was conducted at two farms namely at Nyamurindi farm and Muozi farm which are both located in the highland part of Nyanga district. The Muozi farm is located at an altitude of 1830m above sea level and it falls within the Agro-ecological zone Natural Farming Region I. The rainfall in the area ranges from 900mm to 1200mm annually. The other experimental site, Muozi farm which is located at an altitude of 1900 m above sea level.

1.8 Limitation of the Study

Both trials were rain fed and during the course of the trials, there was a brief mid-season dry spell in January 2020 and this could have slightly affected the amount of moisture that was available to the crops in the field.

CHAPTER 2 REVIEW OF RELATED LITERATURE

2.1 Introduction

The potato (*Solanum tuberosum* L.) belongs to the solanaceae family, genus *Solanum* and is the fourth most important crop after rice, sorghum and maize (Graham *et al*., 2001). Potato originated in South America where it became part to the culture of the Andes, in which farmers grow many different varieties that have a remarkable diversity of colours and shapes. Potatoes spread to the rest of the world after European contact with the Americas in the late 1400s and early 1500s and have since become an important field crop worldwide (Langer, 1975; Acquaah, 2011, Steyn, 2012). It is considered a staple food in most European countries. Potato performs well in cool conditions of temperatures between 16 to 24 degrees Celsius (Lambion *et al.,* 2006) which promotes tuberisation and discourages spread of diseases. Tuber size is very important in determining the end use for potato produce (Allen & Wurr, 1992). Under normal circumstances, large potato tubers are required by the fast foods industry, whereas small tuber sizes are required by the seed potato tubers industry (Allen & Wurr, 1992). This study will answer some very pertinent question on the effect of planting depth on both tuber size and overall tuber yields.

2.2 Economic Importance of Irish Potato

Potato is the third most important crop after maize and wheat. Nutritionally potato is important for its starch and carbohydrates. In order to meet the food needs of the fast increasing world population, it is reckoned that potato is one of the crops that can produce more food (FAO, 2016). Potato has high nutritional, diethetic and wholesome values and its production is expanding on a global scale (Steyn, 2012). Potato is a plant of great importance, being used for direct human consumption, food processing (fried, frozen, dried, sterilised and semi-finished products), industrial processing (starch and distilling industry), and feedstuff and seeds (Liniska, 2004). Corp yield and quality depend mainly on properties of the variety and Agro technical factors (Gruzek, 2009) as well as weather conditions during the production stage (Leszczyuski, 1994). The edible potato being the world's fourth largest crop following rice, wheat and maize has received much attention in terms of research in areas of breeding and agronomy (Ingrams, 1990). Due to limited diversity, and limited number of varieties registered so far, the crop is noted to be very vulnerable to diseases (Schulz, 1996; Acquaah, 2011; Steyn, 2012).

In Zimbabwe, potato is becoming very popular with its importance continuing to rise due to the ever increasing urbanization and uptake of potato products such as French fries and crisps. In 2005, potato was declared a national food security crop with a national target of 30 000 hectares which translates to 600 000mt of the crop per year to meet the country's needs. Its consumption increased from 32 000mt in the year 2000 to 397 600mt in the year 2014 (AMA, 2014). The increase in consumption meant that it has a major position in terms of realised and possible contributions to food security, poverty eradication and economic development in the country consequently leading to growth in demand for both ware and seed potato. Currently Irish potato has the highest return per dollar invested in the country with a guaranteed market. Due to its high demand, there has been growing attraction to potato production. The area under potato production is steadily increasing from 2 000 ha in the year 2000 to 11 360ha in 2014 (AMA, 2014). Furthermore, in Zimbabwe potato production is meant for seed and table potatoes.

Potatoes were established in Zimbabwe by the early twentieth century. Variety trials started in 1911 in Zimbabwe with recorded yields of up to 6t/ha. The yields rose to around 15 t/ha in the late 70s (Joyce, 1988). In 1956, a breeding program was started at Inyanga Research Station. The program expanded and was responsible for the country's seed requirements (Joyce, 1984). Yields at Inyanga Research Station consistently exceeded 50 t/ha in the early 80s (Joyce, 1982a and 1984). Since the 1960s, only the national breeding program was authorized to import potatoes under rigid quarantine procedures only for breeding and evaluation purposes (Joyce, 1982b).

Zimbabwe's emphasis on breeding and seed production was largely based on the need to avoid the introduction of insect pests and pathogens through imported seed potatoes viewed to potentially threaten tobacco production, a very significant cash crop for the country (Joyce,1982a, 1982b, 1988). Since its inception, the breeding program has produced 400 potential varieties, 70 of which have been evaluated in variety trials, out of which more than 12 have so far been distributed to commercial producers (Joyce, 1988). In 1975 the International Potato Centre (CIP) began supplying true seed to the national breeding program (Joyce, 1982a). Joyce (1988) reports average yields of 15 t/ha, up from 6 t/ha in 1970, attributed primarily to the success of the national breeding program.

2.3 Origin of Irish Potato

Potato (*Solanum tuberosum* L.) is a root vegetable crop native to South America. It was first domesticated in the region of Southern Peru and North-western Bolivia between 8000 and 5000 BC and has since spread around the world and is now a staple crop in many countries (Creamer *et al*., 1999). Potato was later introduced to Europe by the Spanish in the second half of the 16th century as part of the Columbian exchange (Struik, 2007). The European mariners then spread it to the rest of the world. Though the potato crop in European farmers, it became an important food crop in the 19th century. However due to lack of genetic diversity, limited number of varieties initially introduced left the crop very vulnerable to diseases. In 1984 a plant disease known as late blight caused by fungus oomycete *Phytophthora infestans.* It spreads rapidly through the poorer communities of western Ireland and parts of the Scottish Highlands resulting in the crop failure that led to the great Irish famine.

2.5 Irish Potato Varieties Registered In Zimbabwe

Potatoes were introduced in Zimbabwe in the early 20th century. The most common varieties then include BP1, Amethyst, Montclair, Opal, Jasper, Emerald and Jacaranda. Most of these varieties have since been phased out like Opal, Emerald and Jacaranda due to some shortcomings in performance noticed in the field (Ackerman 2008). Jacaranda and emerald were good yielding varieties but very susceptible to blights (Geraldine, 2008). However, with the ever-increasing good result of research new varieties were developed which were higher yielding, mature in a short period of time and can tolerate diseases. These varieties are both suitable for summer production where there are high occurrences of diseases and subjected to droughts. They can be grown in irrigations during dry periods. These varieties have opened a window of growing potatoes three times a year, having a summer crop grown in

November/December and harvested in February to March. The second crop is grown in February/March and harvested in May/June and lastly we have the August crop harvested in November and December. These varieties have opened up a window of having a ready crop all year round. Some of the varieties which are being used currently in Zimbabwe are Diamond, Amethyst, Larnoma, BP1, Jasper, Mnandi, Avalanche and of late there are two varieties Labadia and Mondial which is being marketed by Kukura Seeds.

2.5.0 Varieties available in Zimbabwe

2.5.1 Larnoma

A very short seasoned variety which matures in seventy-eight days. A medium yielding variety which has the potential of yielding up to 50 tonnes per hectare The tubers are rounded in shape and they produce medium sized tubers. Tubers have a smooth skin The Larnoma variety is best planted in September because in summer it is very susceptible to leafy diseases.

2.5.2 Amethyst

A late maturing variety which is very tolerant to blights. Amethyst takes about 130 – 140 days to mature. A very high yielding variety which can yield up to 45 tonnes per hectare. Tubers are rounded and white skinned. Can perform very well in summer if supplementary irrigation is provided (Manzira & Ackerman, 2011).

2.5.3 BP1

A medium maturing variety which can mature in 90-100 days. It is susceptible to leaf diseases like blights hence farmers prefer to put it under irrigation in September to December when disease incidence are low. It can yield up to 35 tonnes per hectare.

Produces very good quality tubers with most of the tubers being large sized and very few small sized. BP1 is very sensitive to waterlogged conditions and is susceptible to leaf diseases. However the crop can do very well under irrigation during August to November when disease incidence is very low (Manzira & Ackerman, 2011).

2.5.3 Diamond

A medium maturing variety which takes 90- 100 days to mature. It is high yielding which can yield up to 45tonnes per hectare. Has very quick growth rate that can easily suppress weeds. Diamond is also characterised by quick tuber set and produces medium sized tubers. However, diamond is susceptible to late blight so it's best grown under irrigation (Manzira & Ackerman, 2011).

2.5.4 Mnandi

A medium maturing variety which takes 110-120 days to mature. Has a yield of up to 60 tonnes per hectare but has an average yield of 45 tonnes per hectare. It is quite resistant to blights. Has good quality tubers with excellent keeping quality (Manzira & Ackerman, 2011).

2.5.5 Jasper

Jasper is medium maturing variety which takes 110-120 days. Yields up to 60tonnes per hectare but its average is 45 tonnes per hectare. It does very well under irrigation and produces good quality tubers. Jasper is somehow susceptible to blights hence it is not suitable for summer production (Manzira & Ackerman, 2011).

2.6 The Physiology of Potato tuberization

In the normal growing phase of the potato plant, the stolon emerges from the node of stem underground after sprouting, then starts to grow linearly until onset of tuberization on the stolon tip (Okazawa, 1995). After an elongative growth of the stolon for about two weeks or less, the stolon tips begin to swell afterwards to form tubers (Chapman, 1958). According to histological studies on the progressive development of the stolon and tuber, an accumulation of starch grains started to occur in the vicinity of the endodermis tissue of the stolon tips immediately after ceasing the stolon elongation, and subsequently starch grains spread out all over the tissues of the tuber including the cortex and the pith with an advance of tuber development (Tagawa & Okazawa, 1970).

It has been ascertained that a maximal amount of reducing sugar was accumulated in the stolon tips just before an initiation of their swelling accompanied with a high activity of their respiration, a gradual decrease of sugar content and an increasing accumulation of starch succeeded concomitant decline of respiratory activity, with a lapse of maturing process of the tuber (Tagawa & Okazawa, 1970).

Although the mechanism of potato tuberization is not satisfactorily clarified, evidence at hand points to the fact that the initiation of tuberization is mainly due to the lowering of endogenous gibberellin activity in the stolon tips (Steyn, 2012). An increase in cytokinin may be a reflection of the initiation of tuberization, whereby a rapid cell proliferation in the formed tuber would be elicited and carbohydrates would also be mobilized to this locus for starch accumulation.

2.7 Effects of Plant Depth on potato yields

Planting depth may be one of the important practices that may address the problem of low yields and poor quality in Irish potato. Yield responses of various classes of potato crops varied according to planting methods and ecological zones (Ijoyah & Jimba, 2011). The response of potato cultivars Russet Burbank and Umatilla Russet to planting depth was evaluated during 2000, 2001, and 2002. Russet Burbank stem number increased as seed pieces were planted closer to the soil surface; Umatilla stem number was not affected by planting depth. Despite differences in the emergence rate due to planting depth, total yield was not affected. However, marketable yield and gross income typically declined when seed pieces were planted shallow (10 cm). The largest impact to marketable yield and gross income came from green tubers. Tuber greening was reduced as seed pieces were planted deeper (Wurr, Fellows & Allen, 1993.

Ijoyah & Jimba, (2011) argued that different planting methods such as planting of crops on ridges, mounds (heaps) and occasionally on the flat had been used as standard procedure in crop husbandry uncritically by farmers. The potatoes planted in furrows yielded better than those planted on hills (Lewis & Rowberry, 1973).The shallow planting hastened emergence (Love, Eberlein, Stark & Bohl, 1995; Kouwenhoven, 1970). Other researchers (Masarirambi, Mandisodza, Mashingaidze & Bhebhe, 2012; Burton, 1989; Mangani *et al.*, 2016) reported that deeper planting should hasten emergence due to the availability of water underneath as compared to shallow planting. They also stated that nodes, stolons and tubers per stem were reduced by shallow planting. Further, shallow planted tubers enhanced marketable yield than deeper planted ones (Masarirambi, Mandisodza, Mashingaidze & Bhebhe, 2012; Burton, 1989). They attributed some of the differences in marketable yield to the number of green tubers that were many in shallow plantings.

It has been reported that water movement on the soil surface from the hill to the furrow may hinder the capture of water and nutrients by plants resulting in a negative impact on yield (Lewis & Rowberry, 1973). The differences on water harvesting capabilities between the furrow and hill planting methods are thought to have an impact on crop stress, tuber production and tuber quality. Tubers planted in ridges gave more tubers per plant compared to furrow planting, suggesting that nodes and stolons per stem increased as planting depth increased (Kouwenhoven, 1970; Love, Eberlein, Stark, & Bohl, 1995; Iritani, Weiler, & Knowles, 1983; Bohl & Love, 2005; Allen &W urr, 1992). The number of tubers per plant is purely a varietal character which is genetically controlled, ranging from 6-15 (Thompson &Taylor, 1974).

Irish potato farmers in Zimbabwe use planting methods unverified by scientific study especially when they adopt newer improved varieties. No work to optimize planting method has been done on such varieties. Hence, they achieve very low yields that are below 15t/ha despite that the potential for Irish potato is higher than 60 t/ha.

2.8 Summary

This chapter looked extensively on the literature relating to the potato crop in general and the status of potato production in Zimbabwe in particular. The review also looked at the physiology of tuberization in potatoes and the effect of planting depth on potato yield. The following chapter will look at the methodology used in the research trials.

CHAPTER 3 METHODOLOGY

3.1 The Experimental Sites

The study was conducted from December 2019 to April 2020 at two sites namely; Nyamurindi farm (32.734707 and -18.211506) and Muozi farm (32.033210 and-18.941320) both in Nyanga district. The two sites are situated in the Seed Potato Quarantine area which is in the Agro-Ecological Natural Farming Region one (NFR1) where rainfall ranges from 900mm- 1200mm per Annum, and an average summer temperature of 16 to 24 degrees Celsius. These temperatures are very ideal for potato tuberisation and they reduce multiplication of some leaf diseases. The soils are heavy deep red soils.

3.2 The Experimental Treatments

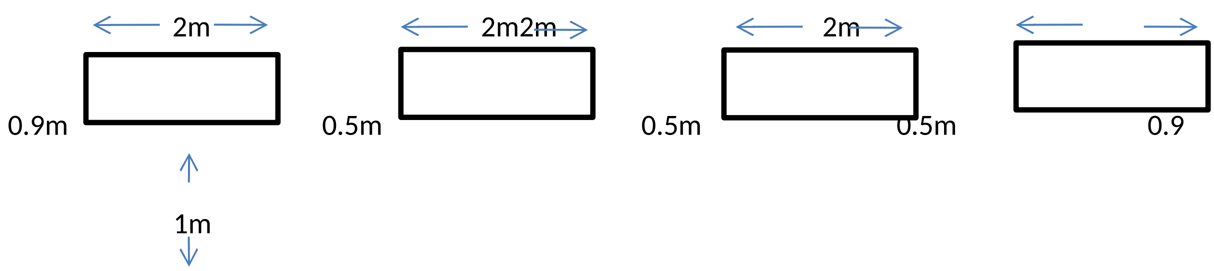
A very short seasoned variety Larnoma which matures in seventy-eight days was used. Four planting depths were used namely; 5 cm, 10 cm, 15 cm and 20. The treatments were replicated four times. The trial was laid out in Randomised Complete

Block Design (RCBD) with field slope as the blocking factor. The trial layout is as shown in figure 2.

3.3 Planting of the Experimental Sites

The two sites Nyamurindi farm and Muozi farm were planted on the same day on 27 December 2019. A double AA grade seed potato Larnoma variety was used. A plant spacing of twenty centimetres in-row spacing and one metre inter-row spacing was used for the trial at both sites. A hand hoe was used to establish the planting stations at the appropriate depths of 5, 10, 15 and 20 cm. Compound C fertiliser NPK (5:18:7) was applied as the basal fertilizer at the rate of 1000 kg/hectare at both sites. This comes to about 25g per planting station. The chemical Nemacur was used for the prevention of nematodes at planting. Each block consisted of one row with seed tubers spaced at 20cm in-row and the block would accommodate 10 plants spaced at 20cm each. Each block therefore had ten potato plant Ammonium nitrate was applied at a rate of 100kg/ha. (2.5g per planting station) Pest control was done to control aphids, cutworms, potato bug and nematodes. Dimethoate insecticide was used for aphids' control and fenvelerate was used to control cutworms. In addition to control of pests, maintenance operations were carried out which included weeding and scouting.

3.4 Design of field Plots



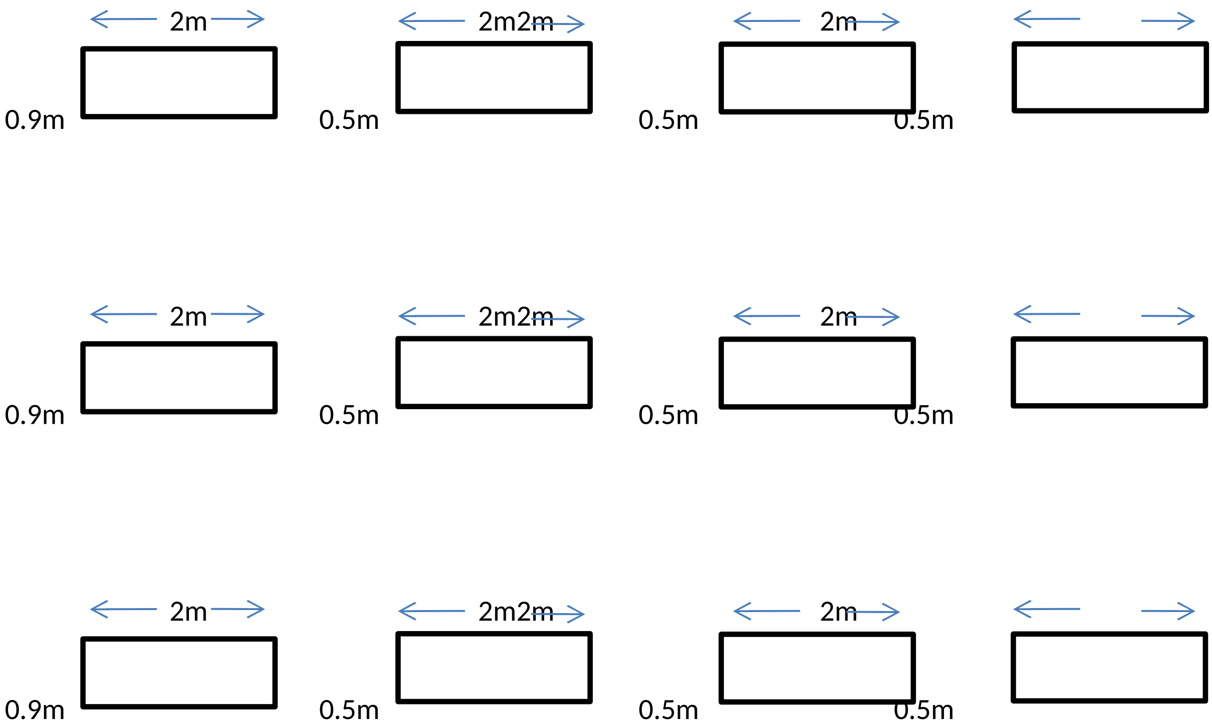


Figure 2. The field layout of the research plots.

3.5 Field data collection

Measurement were taken for the following parameters; percentage emergence, average number of branches per plant, average stem length, average number of tubers per plant, percentage flowering, average weight of tubers per plant and percentage maturity index

3.6 Procedures in measuring different Variables

The procedures used in measuring the different variables are as outlined; to measure the Percentage emergence, average number of branches per plant, the average length of stem from ground to the tip, Percentage flowering and finally to measure the tuber weight which would determine the yield levels. At harvesting tubers were classified into large medium and small size per plot.

3.7 Analysis and organisation of data

Data collected at different growth stages was recorded and these are percentage emergence, stem length, number of branches per station number of tubers per plant weight of tubers. The harvested tubers were graded into three classes, small (30g-44g in diameter, Medium (45g -63g in diameter), Large (greater than 64g). All data collected in the research were subjected to an Analysis of Variance (ANOVA). Data was analysed using Minitab statistical package.

3.8 Ethical Consideration

Permission was granted from the Africa University Research Ethics Committee to conduct the research before the trials began on 27 December 2019. No data was extracted from human subjects. The work of other researchers was duly acknowledged. During the course of the trials, adequate care for the environment was exercised and all chemicals used for pest management were safe to users and the environment. During spraying and other procedures where chemicals were involved care was exercised to ensure that the workers were in full protective clothing. Bio security was provided in all entry gates. Truthful data was collected and the data was analysed and results were presented in an objective manner. Results are going to be shared with the other potato farmers through extension staff in the different potato growing areas in Nyanga District and beyond.

CHAPTER 4 DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

The experiment was conducted at two sites, namely Nyamurindi Farm and Muozi Farm. Both farms are in the Nyanga Seed Potato Plant Quarantine area. The results are presented for each farm starting with Nyamurindi Farm.

4.2 Nyamurindi Farm, Nyanga

4.2.1 Effect of planting depth on Large Average Weight (LAwt), Medium Average Weight (MAwt) and Small Average Weight (SAwt) in kilograms per plot of potato tubers at Nyamurindi Farm, Nyanga.

At Nyamurindi farm there was no significant difference ($p > 0.05$) in the LAwt between the four planting depths. At 5 cm depth the mean LAwt was 0.76kg per plot. At 10 cm depth the mean LAwt was 1.2kg per plot. At 15cm depth the LAwt was 1.08kg per plot and at 20 cm depth the LAwt was 1.3 kg per plot. The results imply that even though there are no significant differences in the LAwt, the 20cm depth had larger LAwt (Table 1). There was no significant difference ($p > 0.05$)in the MAwt between the four planting depths. At 5 cm depth the mean LAwt was 0.9 kg per plot. At 10 cm depth the mean MAwt was 1.24 kg per plot. At 15cm depth the MAwt was 1.2 kg per plot and at 20 cm depth the MAwt was 1.04 kg per plot. The results imply that even though there were no significant differences in the MAwt, the 10cm depth had larger MAwt (Table 1). There was no significant difference ($p > 0.05$) in the SAwt between the four planting depths. At 5 cm depth the mean LAwt was 0.9 kg per plot. At 10 cm depth the mean SAwt was 1.2 kg per plot. At 15 depth the SAwt was 0.9 kg per plot and at 20 cm depth the SAwt was 0.69 kg per plot. The results imply that even though there are were no significant differences in the SAwt, the 10cm depth had larger SAwt (Table 1).

Table 1. Effect of planting depth on LAwt, MAwt and SAwt (kg per plot) of potato tubers at Nyamurindi Farm, Nyanga.

Depth (cm)	LAwt (kg/plot)	MAwt (kg/plot)	SAwt (kg/plot)

5	0.76	0.9	0.9
10	1.2	1.24	1.2
15	1.08	1.2	0.9
20	1.3	1.04	0.69
Pvalue	0.440	0.752	0.297
Significance	NS	NS	NS
LSD	0.776	0.839	0.5256

Cm =centimetre depth; LAwt = large average weight of tubers; MAwt = Average weight of medium sized tubers; Sawt = average weight of small sized tubers; NS= no statistically significant difference. LSD= Least significant difference value

4.2.2 Effect of planting depth on Large Average number (LAN), Medium average Number (MAN) and Small average number (SAN) of potato tubers at Nyamurindi Farm, Nyanga

The number of tubers produced per unit area is important for seed potato production enterprises. In seed potato production the preferable product are smaller sized but numerous tubers. There was no significant difference (p> 0.05) in the LAN between the four planting depths. At 5 cm depth the mean LAN was 4.2 tuber per plot. At 10 cm depth the mean LAN was 6.8 tuber per plt. At 15 depths the mean LAN was 6.0 tuber per plot and at 20 cm depth the LAN was 5.4 tuber per plot. The results imply that even though there are were no significant differences in the LAN, the 10cm depth had the larger number LAN of tubers (Table 2).There was no significant difference (p> 0.05)in the MAN between the four planting depths. At 5 cm depth the mean MAN was 10.2. At 10 cm depth the mean MAN was 14.2 tubers per plot. At 15 depth the mean MAN was 12.8 tuber per plot and at 20 cm depth the mean MAN was 11.2 tuber per plot. The results imply that even though there are were no significant differences in the mean MAN, the 10cm depth had the larger MAN of tubers (Table 2).There was no significant difference (p> 0.05)in the SAN between the four planting depths. At 5 cm depth the mean SAN was 27.4 tuber per plot. At 10 cm depth the mean SAN was 28.4 tubers per plot. At 15 depth the mean SAN was 23.2 tubers per plot and at 20 cm depth the mean SAN was 24.0 tubers per plot. The results imply that even though there are were no significant differences in the mean SAN, the 10cm depth had the larger SAN of tubers (Table 2).

Table.2. Effect of planting depth on LAN, MAN and SAN of potato tubers at Nyamurindi Farm, Nyanga.

Depth (cm)	LAN tubers/plot	MAN tubers/plot	SAN tubers/plot
5	4.2	10.2	27.4
10	6.8	14.2	28.4
15	6.0	12.8	23.2
20	5.4	11.2	24.0
Pvalue	0.678	0.752	0.62
Significance	NS	NS	NS
LSD	4.856	9.43	6.081

Cm = depth in centimetres; LAN = average number of large tubers; MAN = average number of medium sized tubers; SAN = average number of small sized tubers; NS = no statistically significant difference. LSD= least significant difference value.

4.2.3 Effect of planting depth on percentage emergence for weeks 1, 2, 3 and 4 (%EWk1, %EWk2, %EWk3 and %EWk4) at Nyamurindi Farm, Nyanga

There was a significant difference ($p < 0.05$) in the %E at week 1 between the four planting depths. At 5 cm depth the mean %E at week 1 was 60%. At 10 cm depth the mean %E at week 1 was 0%. At 15 depth the mean %E at week 1 was 0% and at 20 cm depth the mean %E at week 1 was 0%. The results imply that a shallow planting depth at 5 cm leads to early emergence (Table 3).There was a significant difference ($p < 0.05$)in the %E at week 2 between the four planting depths. At 5 cm depth the mean %E at week 2 was 99.2%. At 10 cm depth the mean %E at week 2 was 45.4%. At 15 depth the mean %E at week 2 was 0% and at 20 cm depth the mean %E at week 2 was 2.0%.The results imply that a shallow planting depth leads to early emergence

(Table 3).There was a significant difference ($p < 0.05$)in the %E at week 2 between the four planting depths. At 5 cm depth the mean %E at week 3 was 100%. At 10 cm depth the mean %E at week 3 was 92.0%. At 15 depth the mean %E at week 3 was 97.8% and at 20 cm depth the mean %E at week 3 was 69.4%.The results imply that a shallow planting depth leads to early emergence (Table 3).There was no significant difference ($p > 0.05$)in the %E at week 4 between the four planting depths. At 5 cm depth the mean %E at week 4 was 100%E. At 10 cm depth the mean %E at week 4 was 100% E. At 15 depth the mean %E at week 4 was 100%E and at 20 cm depth the mean %E at week 3 was 98% E. The results imply that with time the %E will eventually be the same (Table 3).

Table 3. Effect of planting depth on %EWk1, %EWk2, %EWk3 and %EWk4 at Nyamurindi Farm, Nyanga.

Depth (cm)	Wk1		Wk2		Wk3		Wk4
5	60.6	b	99.2	c	100	b	100
10	0	a	45.4	b	92.0	b	100
15	0	a	0	a	97.8	b	100
20	0	a	2.0	a	69.4	a	100
Pvalue	<0.000		<0.000		0.001		0.418
Significance	***		***		***		NS
LSD	1.797		4.451		14.9		3.081

Cm = planting depth in centimetres; %Ew1 = percentage emergence at week 1; LSD= least significant difference values.

4.2.4 Effect of planting depth on average stem length in centimetres at weeks 3, 4 and 5 (ASLwk3, ASLW4 and ASLWk5) on potato plants at Nyamurindi Farm, Nyanga

There were significant differences ($P<0.05$) in ASL at weeks 3, 4 and 5 as shown in Table 4. At week 3, the 5 cm depth plants had a significantly longer stem length of

10.18 cm followed by the 10 cm depth plants at 3.46 cm (Table 4). The same trend was observed for weeks 4 and 5. (Table 4).

Table 4. Effect of planting depth on ASLwk3, ASLW4 and ASLWk5 (cm) on potato plants at Matema Farm, Nyanga.

Depth (cm)	ASLWk3 (cm)	ASLWk4 (cm)	ASLWk5 (cm)
5	10.18 c	16.82 c	30.2 b
10	3.46 b	11.22 b	31.4 b
15	0.0 a	3.56 a	22.2 a
20	0.0 a	2.08 a	17.72 a
Pvalue	0.000	0.000	0.000
Significance	***	***	***
LSD	0.2599	0.398	7.09

ASLwk3 = average stem length in week three measured in centimetres; LSD= Least significant difference values.

4.2.5 Effect of planting depth on the Average number of haulms per plant at weeks 4 and 5 (ANHwk4 and ANHwk5) at Nyamurindi Farm, Nyanga

There were significant differences (P<0.05) in ANH at week 4 and week5 (Table 5). AT week 4 there were a significantly larger number of haulms per plant for 5 cm depth and 10 cm depth. The same trend was observed for week 5. (Table 5).

Table 5. Effect of planting depth on ANHwk4 and ANHwk5 on potato plants at Nyamurindi Farm, Nyanga.

Depth (cm)	ANHWk4 (haulms per plant)	ANHWk5 (haulms per plant)
5	4.8 b	5.0 b
10	4.2 b	5.8 c
15	2.2 a	4.8 b
20	1.8 a	3.8 a
Pvalue	0.000	0.000
Significance	***	***

LSD	0.654	0.755

ANBwk4 = Average number of haulms in week four; LSD= least significant difference values.

4.2.6 Effect of planting depth on % flowering at week 7, week 8 and week 9 at Nyamurindi Farm, Nyanga

There were significant differences (P<0.05) in %flowering at week 7 and week 8 (Table 6). There were no significant differences (p>0.05) in % flowering at week 9 as all the planting depths had reached 100% flowering (Table 6).

Table 6. Effect of planting depth on % flowering at week 7, week 8 and week 9 at Nyamurindi Farm, Nyanga

Depth (cm)	%FWk7		%FWk8		%FWk9
5	52.2	c	100	c	100
10	25.4	b	61.0	b	100
15	20.8	a	55.0	a	100
20	18.6	a	53.0	a	100
Pvalue	0.000		0.000		0.99
Significance	***		***		NS
LSD	3.456		3.613		0.0

%Fwk7 = percentage flowering of the potato crop; LSD= Least significant difference values.

4.2.7 Effect of planting depth on percentage maturity index (%MI) at week 12, week 13 and week 14.

There were significant differences (p<0.05) in %MI at weeks 12 and 13 but there were no significant differences at week 14 (Table 7).

Table 7. Effect of planting depth on % MI at week 12, week 13 and week14 at Nyamurindi Farm, Nyanga

Depth (cm)	%MIWk12		%MIWk13		%MIWk14
5	50.0	c	100	c	100
10	25.0	b	50.0	b	100
15	20.0	a	50.0	b	100
20	15.0	a	40.0	a	100
Pvalue	0.000		0.000		0.99

Significance	***	***	NS
LSD	4.027	6.65	0.0

% MI= measured as a percentage of the leaf area showing plant maturity.(Maturity Index); NS = Not significant; LSD= Least significant difference values.

4.3. Muozi Farm Nyanga

4.3.1 Effect of planting depth on Large Average Weight (LAwt), Medium Average Weight (MAwt) and Small Average Weight (SAwt) in kilograms per plot of potato tubers at Muozi Farm, Nyanga

At Muozi farm there was no significant difference (p> 0.05) in the LAwt between the four planting depths. At 5 cm depth the mean LAwt was 1.208. At 10 cm depth the mean LAwt was 1.044. At 15 depth the LAwt was 1.186 and at 20 cm depth the LAwt was 1.28. The results imply that even though there are were no significant differences in the LAwt, the 20cm depth had larger LAwt (Table 8). There was no significant difference (p> 0.05)in the MAwt between the four planting depths. At 5 cm depth the mean MAwt was 0.8. At 10 cm depth the mean MAwt was 1.24. At 15 depth the MAwt was 1.2 and at 20 cm depth the MAwt was 1.01.The results imply that even though there are were no significant differences in the MAwt, the 10cm depth had larger MAwt (Table 8). There was no significant difference (p> 0.05) in the SAwt between the four planting depths. At 5 cm depth the mean SAwt was 0.94. At 10 cm depth the mean SAwt was 1.18. At 15 depth the SAwt was 0.814 and at 20 cm depth the SAwt was 0.72.The results imply that even though there are were no significant differences in the SAwt, the 10cm depth had larger SAwt (Table 8).

Table 8. Effect of planting depth on Large Average Weight (LAwt), Medium average weight (MAwt) and small average weight (SAwt) of potato tubers at Muozi Farm, Nyanga.

Depth (cm)	LAWT	MAWT	SAwt

	kg/plot	kg/plot	kg/plot
5	1.08	0.8	0.94
10	1.044	1.05	1.18
15	1.186	0.96	0.814
20	1.280	1.01	0.72
Pvalue	0.569	0.741	0.292
Significance	NS	NS	NS
LSD	0.334	0.5864	0.5358

4.3.2 Effect of planting depth on Large Average number (LAN), Medium average Number (MAN) and Small average number (SAN) of potato tubers at Muozi Farm, Nyanga

There was no significant difference ($p > 0.05$) in the LAN between the four planting depths. At 5 cm depth the mean LAN was 5.2. At 10 cm depth the mean LAN was 7.6. At 15 depth the mean LAN was 6.4 and at 20 cm depth the LAN was 5.6. The results imply that even though there are were no significant differences in the LAN, the 10cm depth had the larger LAN of tubers (Table 9).There was no significant difference ($p > 0.05$)in the MAN between the four planting depths. At 5 cm depth the mean MAN was 10.6. At 10 cm depth the mean MAN was 14.8. At 15 depth the mean MAN was 12.8 and at 20 cm depth the mean MAN was 12.6.The results imply that even though there are were no significant differences in the mean MAN, the 10cm depth had the larger MAN of tubers (Table 9).There was no significant difference ($p > 0.05$)in the SAN between the four planting depths. At 5 cm depth the mean MAN was 24.2. At 10 cm depth the mean SAN was 27.6. At 15 depth the mean SAN was 24.8 and at 20 cm depth the mean SAN was 23.0.The results imply that even though there are were no significant differences in the mean SAN, the 10cm depth had the larger SAN of tubers (Table 9).

Table 9. Effect of planting depth on Large average number (LAN), medium average number (MAN) and Small average number (SAN) of potato tubers at Muozi Farm, Nyanga.

Depth (cm)	LAN (tubers per plot)	MAN (tubers per plot)	SAN (tubers per plot)
5	5.2	10.6	24.2
10	7.6	14.8	27.6
15	6.4	12.8	24.8
20	5.6	12.6	23.0
Pvalue	0.498	0.616	0.660
Significance	NS	NS	NS
LSD	3.65	7.29	6.51

4.3.3 Effect of planting depth on %EWk1, %EWk2, %EWk3 and %EWk4 at Muozi Farm, Nyanga

There was a significant difference ($p< 0.05$) in the %E at week 1 between the four planting depths. At 5 cm depth the mean %E at week 1 was 60.6%. At 10 cm depth the mean %E at week 1 was 0%. At 15 depth the mean %E at week 1 was 0% and at 20 cm depth the mean %E at week 1 was 0%.The results imply that a shallow planting depth at 5 cm leads to early emergence (Table 10).There was a significant difference ($p< 0.05$)in the %E at week 2 between the four planting depths. At 5 cm depth the mean %E at week 2 was 99.2%. At 10 cm depth the mean %E at week 2 was 45.4%. At 15 depth the mean %E at week 2 was 0% and at 20 cm depth the mean %E at week 2 was 2.0%.The results imply that a shallow planting depth leads to early emergence (Table 10).There was a significant difference ($p< 0.05$)in the %E at week 2 between the four planting depths. At 5 cm depth the mean %E at week 3 was 100%. At 10 cm depth the mean %E at week 3 was 92.0%. At 15 depth the mean %E at week 3 was 97.8% and at 20 cm depth the mean %E at week 3 was 69.4%.The results imply that a shallow planting depth leads to early emergence (Table 10).There was no significant difference ($p> 0.05$)in the %E at week 4 between the four planting depths. At 5 cm depth the mean %E at week 4 was 100%E. At 10 cm depth the mean %E at week 4 was 100% E. At 15 depth the mean %E at week 4 was 100%E and at 20 cm depth the mean %E at week 3 was 98% E. The results imply that with time the %E will eventually be the same (Table 10).

Table 10.Effect of planting depth on %EWk1, %EWk2, %EWk3 and %EWk4 at Muozi Farm, Nyanga

Depth (cm)	Wk1		Wk2		Wk3		Wk4
5	60.6	b	93.0	c	100	b	100
10	0	a	43.0	b	92.0	b	100
15	0	a	0	a	97.0	b	100
20	0	a	2.0	a	72.0	a	98
Pvalue	<0.000		<0.000		0.005		0.415
Significance	***		***		**		NS
LSD	1.797		8.96		14.67		3.08

4.3.4 Effect of planting depth on Average plant stem length (ASL) at weeks 3, 4 and 5 at Muozi Farm, Nyanga

There were significant differences (P<0.05) in ASL at weeks 3, 4 and 5 as shown in Table 11.

Table 11. Effect of planting depth on Average stem length (ASL) in centimetres at wk3, W4 and Wk5 at Muozi Farm, Nyanga

Depth (cm)	ASLWk3 (cm)		ASLWk4 (cm)		ASLWk5 (cm)	
5	9.8	c	20.0	c	30.0	b
10	5.2	b	11.4	b	30.8	b
15	0.0	a	5.0	a	21.0	a
20	0.0	a	2.86	a	18.8	a
Pvalue	0.000		0.000		0.000	
Significance	***		***		***	
LSD	0.7		4.208		2.208	

4.3.5 Effect of planting depth on average number of haulms (ANH) at weeks 4 and 5 on potato plants at Muozi Farm, Nyanga

There were significant differences (P<0.05) in ANH at week 4 and week5 (Table 12).

Table 12. Effect of planting depth on Average number of haulms per plant (ANH) at week 4 and week 5 at Muozi Farm, Nyanga.

Depth (cm)	ANHWk4		ANHWk5	
5	5.4	b	5.8	b
10	4.2	b	5.8	b
15	2.6	a	4.2	a
20	2.0	a	3.6	a
Pvalue	0.000		0.000	
Significance	***		***	
LSD	0.796		0.666	

4.3.6 Effect of planting depth on % flowering at week 7, week 8 and week 9 at Muozi Farm, Nyanga

There were significant differences (P<0.05) in %flowering at week 7 and week 8 (Table 13). There were no significant differences (p>0.05) in % flowering at week 9 as all the planting depths had reached 100% flowering (Table 13).

Table 13. Effect of planting depth on % flowering at week 7, week 8 and week 9 at Muozi Farm, Nyanga.

Depth (cm)	%FWk7		%FWk8		%FWk9
5	54.0	c	100	c	100
10	27.0	b	65.0	b	100
15	24.0	a	57.0	a	100
20	20.0	a	54.0	a	100
Pvalue	0.000		0.000		-
Significance	***		***		NS
LSD	4.579		6.066		0.0

4.3.7 Effect of planting depth on %Maturity Index (%MI) at week 12, week 13 and week 14 at Muozi farm, Nyanga.

There were significant differences (p<0.05) in %MI at weeks 12 and 13 but there were no significant differences at week 14 (Table14).

Table 14. Effect of planting depth on % maturity index (%MI) at week 12, week 13 and week14 at Muozi Farm, Nyanga

Depth (cm)	%MIWk12	%MIWk13	%MIWk14

5	50.0	c	100	c	100
10	36.0	b	66.0	b	100
15	30.0	a	51.0	a	100
20	25.0	a	46.0	a	100
Pvalue	0.000		0.000		-
Significance	***		***		NS
LSD	4.027		2.10		0.0

The results imply that the 5 cm depth plants achieved 100 % maturity at week 13 but all the planting depths had reached full maturity by week 14.

4.3 Discussion of Results

4.3.1 Days to emergence

At both sites, there was highly significant ($P<0.01$) variation in respect of days to emergence on planting depth. The results revealed that planting depth at 15 and 20 cm cm took significantly longer days to emergence than depth at 5 cm and depth at 10cm. The delay in emergence in deeper soil depths might be associated with lower soil temperature. (Pavek & Thornton, 2009). Anderson & Cliston, (2010) showed that the rate of development of sprouts from planted seed pieces depends on soil temperature. Very little sprout elongation occurs at 6°C. Elongation is slow at 9°C and is maximized at about 18°C (Hanber *et al*., 2013). The results are also in agreement with findings of Sultana & Rabbani, (2001) who showed that delayed emergence in deeper planted potato crop might be due to the fact that, the potato sprouts had to come across a long distance of the ground to emergence than the shallow planting. Abdulla *et al*., (1993) also showed that percentages of plant emergence were affected by planting depth and seed tubers placed deeper resulted in lowering the plant emergence.

4.3.2 Days to flowering

The observed variation in terms of flowering date could be attributed to the soil moisture at 10 cm suggesting that additional factors such as evaporation, air temperature, and canopy coverage could be influencing soil moisture at this depth (Fernando & Chand, 2006). Almekinders & Struik, (1996) and Sleper & Poehlman, (2006) indicated that flowering in potato is best when abundant moisture, and cool temperatures prevail. Andersen & Cliston, (2010) Tubers form at the end of the stolon and the process of tuber formation coincides with flowering in some varieties.

4.3.3 Number of main haulms per plant

Results from the two trials sites showed that there was a significantly higher number of haulms per plant at the 5 cm and 10 cm planting depths compared to the 15 cm and 20 cm depths. Work by other researchers showed that the number of main stems per station was highly and significantly affected by planting depth. Hanbar *et al*., (2012) showed that the number of stems per plant decreased in deeper planting depth Iritani *et al*., (1983) demonstrated that seed pieces can produce more stems when planted into warmer soils, which may explain why Burbank stem number increased when seed pieces were planted closer to the soil surface.

Throughout emergence and stolon development the shallowest planted seed pieces were exposed to warmer average soil temperatures than those planted deeper.

4.3.4 Total number of tubers

Results from the trials showed that the planting depth of 10 cm on average had the highest total number of tubers per plot. Research by other workers showed that the total tuber number count per hill was highly and significantly affected by planting depth and time of earthing-up. The minimum number of total tuber number count per hill was recorded from no earthing-up combined with planting depth at 10cm. This result agrees with other researchers like Gholipour (1996) who reported that number of produced tubers per plant and unit area decreased as planting depth increased and mentioned the reduction of stem number as its reason. The results from the trials showed that the 10 cm depth had the highest proportion of the tubers harvested both in terms of weight and numbers. Work by other researchers such as Tafirt *et al*., (2010) however showed that the deeper planted potatoes had higher average tuber weights than those planted shallow.

CHAPTER 5 SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

The study was conducted to evaluated the different planting depth at two experimental sites which is Nyamurindi farm and Muozi farm. The two experimental sites are located in Natural Farming Region one (NFR 1). The planting depths used were in centimetres (5, 10, 15 & 20). Planting was done on the same day. Results of the study showed that shallow planting depth (5cm) significantly affected days to emergence, flowering and maturity. Even though it was not very clear as to why at 10cm depth we obtained higher yields than other depths, other researchers have shown that the number of nodes and stolon increase with increasing planting depth which affects the tuber numbers (Stalham *et al*, 2001).

5.2 Discussion

At both sites the results revealed that planting depth at 15 and 20 cm took significantly longer days to emergence than depth at 5 cm and depth at 10cm. The fact that it takes longer for the stolons to emerge from deeper planting holes that from shallow planting holes. The deeper soil depths might also be associated with lower soil temperature that may delay emergence (Pavek & Thornton, 2009). The planting depths at Nyamurindi farm and Muozi farm showed no significant difference ($p<0.05$) in the LAN, MAN and SAN. However, at planting depth 10cm there was a higher number of tubers than other depths. Wurr (1992) recommended that the depth of tubers should be limited to anything up to 10cm to avoid the tubers losing all its nutrients before emergence of the sprout. At seven weeks to nine weeks there was no significant difference ($p<0.05$) in percentage flowering at all the four planting depths. This tallies with notes by Swenson (1962) and Bussan *et al*., (2007) who noted that production of flowers is influenced more by genetic factors than the height of plant or planting depth.This is contrary to findings of Blackmore (1990) where he noted that potatoes planted at deeper depths benefit more on the soil nutrients hence develop large tubers from deeper soils. Similarly there was significant difference at the average weight of medium sized tubers at both Nyamurindi and Muozi Farms. This concurs with observations of Zaggetal (1990) which suggested that at medium depths potato plants tend to have more tubers of average weight in heavy soils From the overall results, the planting depth affects not only the tuber size but also the yield. The higher depths of 20cm affect the yield in that, tuber capacity to feed the stem may be exhausted before the stem emerges. Bohl *et al*. (2001) reported that mother tuber can feed the sprouts for a maximum of a fortnight.

5.3 Conclusion

The results revealed that at 10cm depth a higher yield of all the large, medium and small tubers is achieved at both experimental sites. This confirms the earlier studies by Sirange & Blackmore (1990) where the planting depth of 10cm had higher yields than 20cm depth. It can therefore be concluded that subject results from further trials, farmers are tentatively recommended to use the 10 cm planting depth.

5.4 Implications

The results obtained imply that in heavy soils the depth of 10cm would yield higher because of very favourable soil temperatures at emergence.

5.5 Recommendations

From the study the following recommendations are proposed;

a) There is need to establish demonstration plots at more farms to validate the results from these trials.
b) Basing on the results I therefore recommends potato grower who specialise in Larnoma variety to maintain the planting depth of 10cm in heavy soils where we got the highest yield of marketable tubers.

5.6 Suggestion for further research

a) It is necessary to replicate the same experiment on different soil types to confirm the results.

b) Further trials should be conducted in different Agro ecological Region of Zimbabwe and different soil types in order to test the widespread adaptability of the potato variety Larnoma and its performance under different ecological condition.

REFERENCES

Acquaah, G. (2011). *Principles of Crop Production: Theory, Techniques and Technology*. (2nd Ed.). PHI Learning. 666-687.

Agricultural Marketing Authority (2014). *Commodities Market monitoring* AMA, Harare, Zimbabwe.

Allen, E.J., &Wurr, D.C.E. (2012). Plant Density. In: Harris, P.M. (Ed.). The Potato Crop. The Scientific Basis for Improvement. Chapman &Hall, London. 293-333.

Bohl, W.H., &Love, S.L. (2005). Effect of planting depth and hilling practices on total, and field greening tuber yields. *American Journal of Potato Research*, *82*(6), 441–50.

Burton, W.G. (1998). *The potato*. Longman Group, London.

Chapman, H. W. (2008). Tuberization in the potato plant. *Physiology of Plants, 11*, 215- 224.

CIP, (2007). *Procedure for standard evaluation trials of advanced potato clones. An International Co-operators' Guide.* CIP, Lima, Peru.

DEFRA (2011). Department for Environment, Food and Rural Affairs http://www.fera.defra.gov.uk/plants/publiations/documents/factsheets/pwd.pdf

Getachew T, Derbew B, Tulu S. (2013). Combined effect of plant spacing and time of Earthing up on tuber quality parameters of potato (*Solanum tuberosum*, L) at Degen District, North Showa Zone of Oromia Regional State. *Asia Journal of Crop Science*, *5*(1), 24-32

Gouldine, B. (2001). *Potato Breeding in the Northern Highlands of Uganda*. NARO, Kampala.

Graham T., Van de Fliert, &Compilan, D. (2001). *What happened in participatory Research at the International Potato Centre?* CIP, Lima.

Gopal J., Minocha J.L., & Dhaliwal, H.S. (1998). *Micro tuberization in Irish potato* (*Solanum tuberosum* L.). CIP, Lima.

Hopkins, G. B. Hutchinson, P. J. S., Patterson, P., Miller, J., Thornton, M., Hafez, S., & Alvarez, J. (2004). *Cropping Sequence and Rotation: Impact on Potato Production and Soil Condition*. Paper presented at the Idaho Seed Potato Conferences, Idaho.

Ijoyah, M.O. & Jimba, J. (2011). Effects of planting methods, planting dates and Intercropping systems on sweet potato–okra yields in Makurdi, Nigeria. *Agricultural Science Research Journal*, *1*(8), 184–90.

Iritani, W.M., Weiler, L.D. & Knowles, N.R. (1998). Relationships between stem number, tuber set and yield of Russet Burbank potatoes. *American Journal of Potato Research*, *60*(6), 423–31.

Joyce, M.J., (2002). Potato Production in Zimbabwe. In S. Nganga (Ed.). *Potato Development and Transfer of Technology in Tropical Africa*. International Potato Center, Addis Ababa.

Joyce, M.J., (2002). *Country Presentation: Zimbabwe*. Country Report Presented at the Regional Post-Harvest Workshop, 18-22 June 1984, Nairobi, Kenya. International Potato Centre, Region III.

Joyce, M.J., (2002). *Potato Varietal Development Programme in Zimbabwe*. Paper Presented at the Regional Seed Potato Workshop, Harare, Zimbabwe.

Khalafalla, A.M. (2001). Effect of plant density and seed size on growth and yield of solanum potato in Khartoum State, Sudan. *African Crop Science Journal*, *9*(1), 77–82.

Kouwenhoven, J.K. (1999). Yield, grading and distribution of potatoes in ridges in relation to planting depth and ridge size. *Potato Research*, *13*(1), 59–77.

Langer, W.L. (1997) American foods and Europe population growth 1750–1850. *Journal of Social History*, *8*(2), 51-66.

Lambion, Toulet A, &Traente, M. (2008). *Plant Protection, Cultivation of organic potato*. FAO, Rome.

Lewis W.C., & Rowberry, RG. (2001). Some effects of planting depth and time and height of hilling on Kennebec and Sebago potatoes. *American Journal of Potato Research*, *50*(9), 301–10.

Love, S.L, Eberlein, C.V., Stark, J.C., & Bohl, W.H. (1995). Cultivar and seed piece spacing effects on potato competitiveness with weeds. *American Journal of Potato Research, 72*(4), 197–213.

Mangani, R,Mazarura, U., Mtaita T. A. & Shayanowako, A.(2016). Effect of planting method on growth, yield and quality of three Irish Potato (*Solanum tuberosum*) varieties grown in Zimbabwe. *Annual Research & Review in Biology*, *9*(5), 1-7.

Manzira, C. & Ackerman, K. (2011). *Potato production Manual*. The Seed Potato Association, Harare.

Masarirambi, M.T., Mandisodza, F.C., Mashingaidze, A.B., & Bhebhe, E. (2012). Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*). *International Journal of Agriculture and Biology*, *14*(4), 545–9.

Myhre DL. (1998). Factors affecting specific gravity of potatoes. *Florida State Laboratory Society*, *16*(1), 49–52.

Nielson, M., Iritani, W.M. & Weiler L.D. (1999). Potato seed productivity: Factors influencing eye number per seed piece and subsequent performance. *American Journal of Potato Research*, *66*(3), 151–160.

Nyamapfene, K. (1991). Soils of Zimbabwe. Nehanda Publishers, Harare.

Nyamutukwa, S. (2010). *Seed Production Constraints in the Nyanga Seed Potato Quarantine area*. Seed Services Annual report, Department of Research and Specialists Services, Harare.

Okazawa, Y. (1970). Physiological significance of endogenous cytokinin occurred in potato tubers during their developmental period. *Pro. Crop Sci. Soc. Japan*, *39*, 171-176.

Pavek, M.J. & Thornton, R.E. (2009). Planting Depth Influences Potato Plant Morphology and Economic Value. *American Journal of Potato Research, 86* (1), 56-67

Ricardo, M.C., Jose E.D.P.P., Valdemar. F., Ce'sar, A. B. P. P., &Erika, S. R. (2009). The production of seed potato by hydroponic methods in Brazil: Fruits, vegetables and biotechnology. *Global Science, 1*, 133-139

Steyn, P.J. (2012). Overview of the Potato Plant and Production. In. Denner, F.D.N., Venter, S.L. & Niederweiser, J.G. (Eds*.). Guide to Potato Production in South Africa. Potatoes South Africa* (pp. 19-24). PSA, Pretoria.

Thiart, S., (2012). Seed Potato Production and Cultivar Trends in South Africa. In: Denner, F.D.N., Venter, S.L. & Niederweiser, J.G. (Eds.). *Guide to Potato Production in South Africa. Potatoes South Africa* (pp. 53-59). PSA Pretoria.

Thompson, R. H. &Taylor, H. (1994). Stem density and maturation studies with the potato cultivars Maris peer and Pentland marble. *Potato Research, 17*(1), 51–63.

Vos, J., &Loon, C. D. (1999). Effects of Cropping Frequency on Potato Production. In J. Vos, C. D. Loon & G. J. Bollen (Eds.), *Effects of Crop Rotation on Potato Production in the Temperate Zones: Proceedings of the International*

Conference on Effects of Crop Rotation on Potato Production in the Temperate Zones. Springer Netherlands.

Wangai, A & Lelgut, D. (2001). Status of potato virus in Africa. In Hughes J.A. & Babajide, O. Odu (Eds.). *Proceedings of a Conference Organised by International Institute of Tropical Agriculture on Potato Virology*. IITA Press.

Wurr, D.C.E, Fellows, J.R., &Allen, E.J. (1993). An approach to determining optimum tuber planting densities in early potato varieties. *Journal of Agricultural Science, 120*, 63–70.

APPENDICES

Appendix 1 Analysis Results for Nyamurindi Farm

1a One-way ANOVA: LAWt versus Treatment

Analysis of Variance for LAWt

Source	DF	SS	MS	F	P
Treatmen	3	0.825	0.275	0.95	0.440
Error	16	4.640	0.290		
Total	19	5.466			

Individual 95% CIs For Mean
Based on Pooled StDev

```
Level        N      Mean     StDev  ------+---------+---------+---------+
1            5    0.7600    0.5595   (---------*---------)
2            5    1.2000    0.5701            (---------*---------)
3            5    1.0800    0.4604         (----------*---------)
4            5    1.3000    0.5568              (---------*---------)
                                    ------+---------+---------+---------+
Pooled StDev =    0.5385                0.50      1.00      1.50      2.00
```

1b One-way ANOVA: MAWt versus Treatment

```
Analysis of Variance for MAWt
Source     DF        SS        MS        F        P
Treatmen    3     0.365     0.122     0.40    0.752
Error      16     4.824     0.302
Total      19     5.190
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  -+---------+---------+---------+-----
1            5    0.9000    0.4416  (------------*------------)
2            5    1.2400    0.4278           (------------*------------)
3            5    1.2000    0.4472          (------------*------------)
4            5    1.0400    0.7925      (------------*------------)
                                    -+---------+---------+---------+-----
Pooled StDev =    0.5491           0.40      0.80      1.20      1.60
```

1c One-way ANOVA: SAWt versus Treatment

```
Analysis of Variance for SAWt
Source     DF        SS        MS        F        P
Treatmen    3     0.660     0.220     1.34    0.297
Error      16     2.632     0.164
Total      19     3.292
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  --+---------+---------+---------+----
1            5    0.9000    0.3317         (----------*----------)
2            5    1.2000    0.6782                 (----------*----------)
3            5    0.9000    0.2646         (----------*----------)
4            5    0.6900    0.1342   (----------*----------)
                                    --+---------+---------+---------+----
Pooled StDev =    0.4056            0.35      0.70      1.05      1.40
```

1d One-way ANOVA: LAN versus Treatment

```
Analysis of Variance for LAN
Source     DF        SS        MS        F        P
Treatmen    3      18.0       6.0     0.51    0.678
Error      16     186.8      11.7
Total      19     204.8
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  -------+---------+---------+---------
1            5     4.200     3.033   (------------*------------)
2            5     6.800     4.550            (------------*------------)
3            5     6.000     3.317         (------------*------------)
4            5     5.400     2.408       (------------*------------)
                                    -------+---------+---------+---------
```

```
Pooled StDev =    3.417                 2.5       5.0       7.5
```

1e One-way ANOVA: MAN versus Treatment

```
Analysis of Variance for MAN
Source     DF        SS        MS        F        P
Treatmen    3      46.6      15.5     0.40    0.752
Error      16     615.2      38.5
Total      19     661.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
1           5    10.200     5.630   (----------*-----------)
2           5    14.200     4.868           (----------*-----------)
3           5    12.800     3.768        (-----------*----------)
4           5    11.200     9.176     (----------*-----------)
                                   --+---------+---------+---------+----
Pooled StDev =    6.201            5.0      10.0      15.0      20.0
```

1f One-way ANOVA: SAN versus Treatment

```
Analysis of Variance for SAN
Source     DF        SS        MS        F        P
Treatmen    3      96.5      32.2     0.61    0.620
Error      16     847.2      53.0
Total      19     943.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
1           5    27.400     6.768         (-----------*----------)
2           5    28.400     8.142           (----------*-----------)
3           5    23.200     6.380  (-----------*----------)
4           5    24.000     7.681    (----------*----------)
                                   ---+---------+---------+---------+---
Pooled StDev =    7.277            18.0      24.0      30.0      36.0
```

1g One-way ANOVA: %E WK1 versus Treatment

```
Analysis of Variance for %E WK1
Source     DF        SS        MS        F        P
Treatmen3  13771.35   4590.45  2700.26    0.000
Error      16     27.20      1.70
Total      19  13798.55
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    60.600     2.608                                   *)
2           5     0.000     0.000  (*)
3           5     0.000     0.000  (*)
4           5     0.000     0.000  (*)
                                   -+---------+---------+---------+-----
Pooled StDev =    1.304             0        20        40        60
```

1h One-way ANOVA: %E WK2 versus Treatment

```
Analysis of Variance for %E WK2
```

```
Source      DF        SS        MS        F        P
Treatmen3  32664.55  10888.18  1209.80    0.000
Error      16    144.00      9.00
Total      19  32808.55
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5     99.20      1.79                                   (*)
2           5     45.40      3.58                 (*)
3           5      0.00      0.00  (*)
4           5      2.00      4.47   (*)
                                   -+---------+---------+---------+-----
Pooled StDev =     3.00             0        30        60        90
```

1i One-way ANOVA: %E WK3 versus Treatment

```
Analysis of Variance for %E WK3
Source      DF        SS        MS        F        P
Treatmen     3      2945       982     9.19    0.001
Error       16      1710       107
Total       19      4655
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    100.00      0.00                      (------*-----)
2           5     92.00      7.58                 (-----*------)
3           5     97.80      3.03                     (-----*------)
4           5     69.40     18.99   (-----*------)
                                   -+---------+---------+---------+-----
Pooled StDev =    10.34            60        75        90       105
```

1j One-way ANOVA: %E WK4 versus Treatment

```
Analysis of Variance for %E WK4
Source      DF        SS        MS        F        P
Treatmen     3     15.00      5.00     1.00    0.418
Error       16     80.00      5.00
Total       19     95.00
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    100.00      0.00            (----------*----------)
2           5    100.00      0.00            (----------*----------)
3           5    100.00      0.00            (----------*----------)
4           5     98.00      4.47  (----------*----------)
                                   -+---------+---------+---------+-----
Pooled StDev =     2.24          96.0      98.0     100.0     102.0
```

1k One-way ANOVA: ASLWK3 versus Treatment

```
Analysis of Variance for ASLWK3
Source      DF        SS        MS        F        P
Treatmen3  345.4580  115.1527  2362.11    0.000
Error      16    0.7800    0.0488
Total      19  346.2380
```

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    10.180     0.217                                   (*)
2           5     3.460     0.385              (*
3           5     0.000     0.000  (*)
4           5     0.000     0.000  (*)
                                   -+---------+---------+---------+-----
Pooled StDev =    0.221            0.0       3.0       6.0       9.0
```

1l One-way ANOVA: ASLWK4 versus Treatment

```
Analysis of Variance for ASLWK4
Source     DF        SS        MS        F        P
Treatmen    3    711.08    237.03   122.51    0.000
Error      16     30.96      1.93
Total      19    742.03
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1           5    16.820     2.695                               (--*-)
2           5    11.220     0.438                    (-*--)
3           5     3.560     0.518     (--*--)
4           5     2.080     0.130   (-*--)
                                   ---------+---------+---------+-------
Pooled StDev =    1.391                   5.0      10.0      15.0
```

1m One-way ANOVA: ASLWK5 versus Treatment

```
Analysis of Variance for ASLWK5
Source     DF        SS        MS        F        P
Treatmen    3    641.30    213.77    51.23    0.000
Error      16     66.77      4.17
Total      19    708.07
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1           5    30.200     0.447                          (--*---)
2           5    31.400     3.782                            (---*---)
3           5    22.200     1.304            (--*---)
4           5    17.720     0.701   (--*---)
                                   ---------+---------+---------+-------
Pooled StDev =    2.043                  20.0      25.0      30.0
```

1n One-way ANOVA: ANBWK4 versus Treatment

```
Analysis of Variance for ANBWK4
Source     DF        SS        MS        F        P
Treatmen    3    32.550    10.850    54.25    0.000
Error      16     3.200     0.200
Total      19    35.750
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1           5    4.8000    0.4472                         (---*---)
2           5    4.2000    0.4472                    (---*---)
3           5    2.2000    0.4472      (--*---)
4           5    1.8000    0.4472  (---*---)
                                   ---------+---------+---------+-------
Pooled StDev =   0.4472                   2.4       3.6       4.8
```

1o One-way ANOVA: ANBWK5 versus Treatment

```
Analysis of Variance for ANBWK5
Source     DF        SS        MS        F        P
Treatmen    3    10.150     3.383    12.30    0.000
Error      16     4.400     0.275
Total      19    14.550
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           5    5.0000    0.0000              (----*----)
2           5    5.8000    0.4472                      (----*----)
3           5    4.8000    0.8367            (----*----)
4           5    3.8000    0.4472  (----*----)
                                   -------+---------+---------+---------
Pooled StDev =   0.5244                 4.0       5.0       6.0
```

1p One-way ANOVA: %F WK7 versus Treatment

```
Analysis of Variance for %F WK7
Source     DF        SS        MS        F        P
Treatmen    3   3631.75   1210.58   206.06    0.000
Error      16     94.00      5.88
Total      19   3725.75
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           5    52.200     4.382                                (-*)
2           5    25.400     1.140        (-*-)
3           5    20.800     1.095    (-*-)
4           5    18.600     1.342   (-*)
                                   -------+---------+---------+---------
Pooled StDev =    2.424                  24        36        48
```

1q One-way ANOVA: %F WK8 versus Treatment

```
Analysis of Variance for %F WK8
Source     DF        SS        MS        F        P
Treatmen    3   7323.75   2441.25   260.40    0.000
Error      16    150.00      9.38
Total      19   7473.75
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           5    100.00      0.00                                  (-*-)
2           5     61.00      2.24        (-*-)
3           5     55.00      3.54    (-*-)
4           5     53.00      4.47  (-*-)
                                   -------+---------+---------+---------
Pooled StDev =     3.06                  60        75        90
```

1r One-way ANOVA: %F WK9 versus Treatment

```
Analysis of Variance for %F WK9
Source     DF        SS        MS        F        P
Treatmen    3 0.0000000 0.0000000        *        *
Error      16 0.0000000 0.0000000
Total      19 0.0000000
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5   100.000     0.000  *
2           5   100.000     0.000  *
3           5   100.000     0.000  *
4           5   100.000     0.000  *
                                   ----------+---------+---------+------
Pooled StDev =    0.000                 100.010   100.020   100.030
```

1s One-way ANOVA: %MI WK12 versus Treatment

```
Analysis of Variance for %MI WK12
Source     DF        SS        MS        F        P
Treatmen3  3625.000  1208.333       *        *
Error      16     0.000     0.000
Total      19  3625.000
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
1           5   50.0000    0.0000                                      *
2           5   25.0000    0.0000            *
3           5   20.0000    0.0000       *
4           5   15.0000    0.0000  *
                                   -----+---------+---------+---------+-
Pooled StDev =   0.0000                20        30        40        50
```

1t One-way ANOVA: %MI WK 13 versus Treatment

```
Analysis of Variance for %MI WK 1
Source     DF        SS        MS        F        P
Treatmen3  11000.00   3666.67       *        *
Error      16      0.00      0.00
Total      19  11000.00
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5   100.000     0.000                              *
2           5    50.000     0.000       *
3           5    50.000     0.000       *
4           5    40.000     0.000  *
                                   ----------+---------+---------+------
Pooled StDev =    0.000                     60        80       100
```

1u One-way ANOVA: %MI WK14 versus Treatment

```
Analysis of Variance for %MI WK14
Source     DF        SS        MS        F        P
Treatmen    3 0.0000000 0.0000000        *        *
Error      16 0.0000000 0.0000000
Total      19 0.0000000
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5   100.000     0.000  *
2           5   100.000     0.000  *
3           5   100.000     0.000  *
4           5   100.000     0.000  *
                                   ----------+---------+---------+------
Pooled StDev =    0.000                 100.010   100.020   100.030
```

1v One-way ANOVA: SDLV versus Treatment

```
Analysis of Variance for SDLV
Source     DF        SS        MS        F        P
Treatmen3  3149.408  1049.803  1850.28    0.000
Error      16     9.078     0.567
Total      19  3158.486
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
1           5    70.120     0.657         (*)
2           5    94.400     0.894                                   *)
```

```
3           5    64.600     0.548    (*
4           5    63.350     0.859   *)
                                   --------+---------+---------+--------
Pooled StDev =    0.753                  70        80        90
```

1w One-way ANOVA: SDMV versus Treatment

```
Analysis of Variance for SDMV
Source     DF        SS        MS        F        P
Treatmen    3    1249.8     416.6    23.47    0.000
Error      16     284.0      17.8
Total      19    1533.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    35.400     0.548                          (-----*----)
2           5    22.200     5.718         (-----*----)
3           5    35.600     0.548                          (-----*-----)
4           5    17.800     6.140   (----*-----)
                                   -+---------+---------+---------+-----
Pooled StDev =    4.213          14.0      21.0      28.0      35.0
```

1x One-way ANOVA: SDSV versus Treatment

```
Analysis of Variance for SDSV
Source     DF        SS        MS        F        P
Treatmen    3     51.70     17.23    11.83    0.000
Error      16     23.31      1.46
Total      19     75.01
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           5     9.800     0.447  (-----*-----)
2           5    10.400     0.548     (-----*-----)
3           5    10.160     0.358    (-----*-----)
4           5    13.800     2.280                    (-----*-----)
                                   -------+---------+---------+---------
Pooled StDev =    1.207                10.0      12.0      14.0
```

1y One-way ANOVA: SDLW versus Treatment

```
Analysis of Variance for SDLW
Source     DF        SS        MS        F        P
Treatmen    3   0.00586   0.00195     0.48    0.701
Error      16   0.06524   0.00408
Total      19   0.07110
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1           5   0.18400   0.01475   (-----------*-----------)
2           5   0.20960   0.08197        (-----------*-----------)
3           5   0.22200   0.06535          (-----------*------------)
4           5   0.18150   0.07145  (-----------*-----------)
                                   ------+---------+---------+---------+
Pooled StDev=  0.06386                 0.150     0.200     0.250     0.300
```

1z One-way ANOVA: SDMW versus Treatment

```
Analysis of Variance for SDMW
Source     DF        SS        MS        F        P
Treatmen    3    0.1015    0.0338     0.98    0.426
Error      16    0.5516    0.0345
Total      19    0.6531
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
```

```
1           5    0.0688    0.0317   (-----------*----------)
2           5    0.0680    0.0164   (-----------*----------)
3           5    0.0958    0.0086     (----------*-----------)
4           5    0.2400    0.3695            (-----------*-----------)
                                   ---------+---------+---------+--------
Pooled StDev =   0.1857                  0.00      0.15      0.30
```

One-way ANOVA: SDSW versus Treatment

```
Analysis of Variance for SDSW
Source     DF        SS        MS        F        P
Treatmen    3 0.0003346 0.0001115     1.64    0.221
Error      16 0.0010904 0.0000682
Total      19 0.0014250
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
1           5  0.028000  0.007583  (---------*---------)
2           5  0.030600  0.009476     (---------*---------)
3           5  0.038400  0.008385             (---------*---------)
4           5  0.029000  0.007416   (---------*---------)
                                   -----+---------+---------+---------+-
Pooled StDev = 0.008255               0.0240    0.0320    0.0400    0.0480
```

Appendix 2 Analysis Results for Muozi farm

2a One-way ANOVA: LAWt versus Treatment

```
Analysis of Variance for LAWt
Source     DF        SS        MS        F        P
Treatmen    3    0.1466    0.0489     0.69    0.569
Error      16    1.1275    0.0705
Total      19    1.2741
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    1.2080    0.3199           (-----------*------------)
2           5    1.0440    0.1539   (-----------*------------)
3           5    1.1860    0.2527          (-----------*------------)
4           5    1.2800    0.3033              (------------*------------)
                                   -+---------+---------+---------+-----
Pooled StDev =   0.2655           0.80      1.00      1.20      1.40
```

2b One-way ANOVA: MAWt versus Treatment

```
Analysis of Variance for MAWt
Source     DF        SS        MS        F        P
Treatmen    3     0.180     0.060     0.42    0.741
Error      16     2.294     0.143
Total      19     2.475
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1           5    0.8000    0.3240   (-----------*-----------)
2           5    1.0500    0.4243           (-----------*-----------)
3           5    0.9600    0.2702        (-----------*-----------)
4           5    1.0100    0.4642          (-----------*-----------)
                                   ------+---------+---------+---------+
Pooled StDev =   0.3786                0.60      0.90      1.20      1.50
```

2c One-way ANOVA: SAWt versus Treatment

```
Analysis of Variance for SAWt
Source     DF        SS        MS        F        P
Treatmen    3     0.595     0.198     1.36    0.292
Error      16     2.340     0.146
Total      19     2.935
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5    0.9400    0.2966        (----------*---------)
2           5    1.1800    0.5495               (----------*---------)
3           5    0.8140    0.4278     (---------*----------)
4           5    0.7200    0.1095  (----------*---------)
                                   ----------+---------+---------+------
Pooled StDev =   0.3824                    0.70      1.05      1.40
```

2d One-way ANOVA: LAN versus Treatment

```
Analysis of Variance for LAN
Source     DF        SS        MS        F        P
Treatmen    3     16.80      5.60     0.83    0.498
Error      16    108.40      6.78
Total      19    125.20
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           5     5.200     1.789   (-----------*-----------)
2           5     7.600     3.209               (-----------*-----------)
3           5     6.400     2.608         (-----------*-----------)
4           5     5.600     2.608     (-----------*-----------)
                                   -------+---------+---------+---------
Pooled StDev =    2.603                 4.0       6.0       8.0
```

2e One-way ANOVA: MAN versus Treatment

```
Analysis of Variance for MAN
Source     DF        SS        MS        F        P
Treatmen    3      44.2      14.7     0.61    0.616
Error      16     384.0      24.0
Total      19     428.2
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1           5    10.600     5.079   (----------*-----------)
2           5    14.800     5.630             (-----------*-----------)
3           5    12.800     3.114        (-----------*-----------)
4           5    12.600     5.367        (----------*-----------)
                                   ------+---------+---------+---------+
Pooled StDev =    4.899                8.0      12.0      16.0      20.0
```

2f One-way ANOVA: SAN versus Treatment

```
Analysis of Variance for SAN
Source     DF        SS        MS        F        P
Treatmen    3      57.0      19.0     0.54    0.660
Error      16     560.8      35.1
Total      19     617.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1           5    24.200     5.215     (----------*-----------)
2           5    27.600     5.550            (----------*----------)
```

```
3           5    24.800     6.419      (-----------*----------)
4           5    23.000     6.403   (----------*----------)
                                   ------+---------+---------+---------+
Pooled StDev =    5.920               20.0      25.0      30.0      35.0
```

2g One-way ANOVA: %E WK1 versus Treatment

```
Analysis of Variance for %E WK1
Source     DF        SS        MS        F        P
Treatmen3  13771.35   4590.45  2700.26    0.000
Error      16     27.20      1.70
Total      19  13798.55
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    60.600     2.608                                 *)
2           5     0.000     0.000  (*)
3           5     0.000     0.000  (*)
4           5     0.000     0.000  (*)
                                   -+---------+---------+---------+-----
Pooled StDev =    1.304             0        20        40        60
```

2h One-way ANOVA: %E WK2 versus Treatment

```
Analysis of Variance for %E WK2
Source     DF        SS        MS        F        P
Treatmen    3   28705.0    9568.3   283.51    0.000
Error      16     540.0      33.8
Total      19   29245.0
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
1           5    93.000     6.708                                 (-*-)
2           5    43.000     8.367               (-*-)
3           5     0.000     0.000  (-*-)
4           5     2.000     4.472   (-*-)
                                   --+---------+---------+---------+----
Pooled StDev =    5.809              0        30        60        90
```

2i One-way ANOVA: %E WK3 versus Treatment

```
Analysis of Variance for %E WK3
Source     DF        SS        MS        F        P
Treatmen    3      2384       795     6.23    0.005
Error      16      2040       128
Total      19      4424
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5    100.00      0.00                    (------*------)
2           5     92.00      8.37              (------*------)
3           5     97.00      4.47                  (------*------)
4           5     72.00     20.49   (------*------)
                                   ----------+---------+---------+------
Pooled StDev =    11.29                     75        90       105
```

2j One-way ANOVA: %E WK4 versus Treatment

```
Analysis of Variance for %E WK4
Source     DF        SS        MS        F        P
Treatmen    3     15.00      5.00     1.00    0.418
Error      16     80.00      5.00
Total      19     95.00
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
```

```
1           5    100.00      0.00            (----------*----------)
2           5    100.00      0.00            (----------*----------)
3           5    100.00      0.00            (----------*----------)
4           5     98.00      4.47  (----------*----------)
                                   -+---------+---------+---------+-----
Pooled StDev =     2.24         96.0      98.0     100.0     102.0
```

2k One-way ANOVA: ASLWK3 versus Treatment

```
Analysis of Variance for ASLWK3
Source     DF        SS        MS        F        P
Treatmen    3   334.150   111.383   495.04    0.000
Error      16     3.600     0.225
Total      19   337.750
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
1           5     9.800     0.447                                  (-*)
2           5     5.200     0.837                  (*-)
3           5     0.000     0.000   (*)
4           5     0.000     0.000   (*)
                                   --+---------+---------+---------+----
Pooled StDev =    0.474            0.0       3.0       6.0       9.0
```

2l One-way ANOVA: ASLwk4 versus Treatment

```
Analysis of Variance for ASLwk4
Source     DF        SS        MS        F        P
Treatmen    3    889.01    296.34    54.13    0.000
Error      16     87.59      5.47
Total      19    976.61
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1           5    20.000     1.225                              (--*---)
2           5    11.400     4.278                (---*---)
3           5     5.000     0.707      (--*---)
4           5     2.860     1.264  (---*--)
                                   ---------+---------+---------+-------
Pooled StDev =    2.340                  6.0      12.0      18.0
```

2m One-way ANOVA: ASLWK5 versus Treatment

```
Analysis of Variance for ASLWK5
Source     DF        SS        MS        F        P
Treatmen    3    564.95    188.32    72.43    0.000
Error      16     41.60      2.60
Total      19    606.55
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1           5    30.000     1.225                       (--*--)
2           5    30.800     2.775                         (--*--)
3           5    21.000     0.707       (--*--)
4           5    18.800     0.837   (--*--)
                                   ------+---------+---------+---------+
Pooled StDev =    1.612               20.0      25.0      30.0      35.0
```

2n One-way ANOVA: ANBWK4 versus Treatment

```
Analysis of Variance for ANBWK4
Source     DF        SS        MS        F        P
Treatmen    3    35.750    11.917    36.67    0.000
Error      16     5.200     0.325
Total      19    40.950
                                   Individual 95% CIs For Mean
```

```
                                         Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    5.4000    0.8944                         (---*---)
2           5    4.2000    0.4472                 (---*---)
3           5    2.6000    0.5477      (--*---)
4           5    2.0000    0.0000  (--*---)
                                   -+---------+---------+---------+-----
Pooled StDev =   0.5701           1.5       3.0       4.5       6.0
```

2o One-way ANOVA: ANBWK5 versus Treatment

```
Analysis of Variance for ANBWK5
Source     DF        SS        MS        F        P
Treatmen    3    18.950     6.317    28.07    0.000
Error      16     3.600     0.225
Total      19    22.550
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1           5    5.8000    0.4472                         (---*---)
2           5    5.8000    0.4472                         (---*---)
3           5    4.2000    0.4472        (---*---)
4           5    3.6000    0.5477  (---*---)
                                   ---------+---------+---------+-------
Pooled StDev =   0.4743                  4.0       5.0       6.0
```

2p One-way ANOVA: %F WK7 versus Treatment

```
Analysis of Variance for %F WK7
Source     DF        SS        MS        F        P
Treatmen    3    3573.8    1191.3    86.64    0.000
Error      16     220.0      13.8
Total      19    3793.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           5    54.000     5.477                               (--*--)
2           5    27.000     2.739         (--*-)
3           5    24.000     4.183     (--*--)
4           5    20.000     0.000  (--*--)
                                   -------+---------+---------+---------
Pooled StDev =    3.708                 24        36        48
```

2q One-way ANOVA: %F WK8 versus Treatment

```
Analysis of Variance for %F WK8
Source     DF        SS        MS        F        P
Treatmen    3    6730.0    2243.3    89.73    0.000
Error      16     400.0      25.0
Total      19    7130.0
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
1           5    100.00      0.00                                  (--*--)
2           5     65.00      7.07          (--*--)
3           5     57.00      4.47     (--*--)
4           5     54.00      5.48  (--*--)
                                   --------+---------+---------+--------
Pooled StDev =     5.00                  60        75        90
```

2r One-way ANOVA: %F WK9 versus Treatment

```
Analysis of Variance for %F WK9
Source     DF        SS        MS        F        P
Treatmen    3 0.0000000 0.0000000        *        *
```

```
Error      16 0.0000000 0.0000000
Total      19 0.0000000
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5   100.000     0.000  *
2           5   100.000     0.000  *
3           5   100.000     0.000  *
4           5   100.000     0.000  *
                                   ----------+---------+---------+------
Pooled StDev =    0.000                  100.010   100.020   100.030
```

2s One-way ANOVA: %MI WK12 versus Treatment

```
Analysis of Variance for %MI WK12
Source     DF        SS        MS        F        P
Treatmen    3    1753.8     584.6    34.64    0.000
Error      16     270.0      16.9
Total      19    2023.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1           5    50.000     0.000                         (---*---)
2           5    36.000     4.183            (---*---)
3           5    30.000     5.000      (---*---)
4           5    25.000     5.000  (---*---)
                                   ---------+---------+---------+-------
Pooled StDev =    4.108                    30        40        50
```

2t One-way ANOVA: %MI WK 13 versus Treatment

```
Analysis of Variance for %MI WK 1
Source     DF        SS        MS        F        P
Treatmen    3    8903.8    2967.9    52.18    0.000
Error      16     910.0      56.9
Total      19    9813.8
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    100.00      0.00                           (---*---)
2           5     66.00     10.84           (---*---)
3           5     51.00      5.48     (---*--)
4           5     46.00      8.94  (---*---)
                                   -+---------+---------+---------+-----
Pooled StDev =     7.54            40        60        80        100
```

2u One-way ANOVA: %MI WK14 versus Treatment

```
Analysis of Variance for %MI WK14
Source     DF        SS        MS        F        P
Treatmen    3 0.0000000 0.0000000        *        *
Error      16 0.0000000 0.0000000
Total      19 0.0000000
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1           5   100.000     0.000  *
2           5   100.000     0.000  *
3           5   100.000     0.000  *
4           5   100.000     0.000  *
                                   ----------+---------+---------+------
Pooled StDev =    0.000                  100.010   100.020   100.030
```

2v One-way ANOVA: SDLV versus Treatment

```
Analysis of Variance for SDLV
Source     DF        SS        MS        F        P
Treatmen    3   2411.60    803.87   284.55    0.000
Error      16     45.20      2.83
Total      19   2456.80
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
1           5    71.800     2.049         (-*)
2           5    91.800     2.387                             (-*)
3           5    65.200     0.837   (*-)
4           5    64.800     0.837  (-*)
                                   -------+---------+---------+---------
Pooled StDev =    1.681                  70        80        90
```

2w One-way ANOVA: SDMV versus Treatment

```
Analysis of Variance for SDMV
Source     DF        SS        MS        F        P
Treatmen    3    1062.8     354.3    22.75    0.000
Error      16     249.2      15.6
Total      19    1312.0
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
1           5    35.400     0.548                        (-----*----)
2           5    22.400     5.320       (----*----)
3           5    35.000     0.707                        (----*----)
4           5    19.200     5.762  (----*-----)
                                   --------+---------+---------+--------
Pooled StDev =    3.947                  21.0      28.0      35.0
```

2x One-way ANOVA: SDSV versus Treatment

```
Analysis of Variance for SDSV
Source     DF        SS        MS        F        P
Treatmen    3     30.60     10.20     6.00    0.006
Error      16     27.20      1.70
Total      19     57.80
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1           5    11.400     1.342       (------*-------)
2           5    10.800     0.837   (-------*------)
3           5    11.400     1.140       (------*-------)
4           5    14.000     1.732                     (-------*------)
                                   -+---------+---------+---------+-----
Pooled StDev =    1.304           9.6      11.2      12.8      14.4
```

2y One-way ANOVA: SDLW versus Treatment

```
Analysis of Variance for SDLW
Source     DF        SS        MS        F        P
Treatmen    3    0.0549    0.0183     1.04    0.403
Error      16    0.2824    0.0176
Total      19    0.3373
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1           5    0.1740    0.0329  (----------*---------)
2           5    0.2120    0.0800     (----------*---------)
3           5    0.3060    0.2409           (----------*---------)
4           5    0.1825    0.0713   (---------*----------)
```

```
                                   ------+---------+---------+---------+
Pooled StDev =   0.1329                0.12      0.24      0.36      0.48
```

2z One-way ANOVA: SDMW versus Treatment

```
Analysis of Variance for SDMW
Source     DF        SS        MS        F        P
Treatmen    3    0.1015    0.0338     0.98    0.426
Error      16    0.5516    0.0345
Total      19    0.6531
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
1           5    0.0688    0.0317   (-----------*----------)
2           5    0.0680    0.0164   (-----------*----------)
3           5    0.0958    0.0086     (----------*-----------)
4           5    0.2400    0.3695              (-----------*-----------)
                                   --------+---------+---------+--------
Pooled StDev =   0.1857                  0.00      0.15      0.30
```

One-way ANOVA: SDSW versus Treatment

```
Analysis of Variance for SDSW
Source     DF        SS        MS        F        P
Treatmen    3 0.0003346 0.0001115     1.64    0.221
Error      16 0.0010904 0.0000681
Total      19 0.0014250
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
1           5  0.028000  0.007583  (---------*---------)
2           5  0.030600  0.009476     (---------*---------)
3           5  0.038400  0.008385               (---------*---------)
4           5  0.029000  0.007416   (---------*---------)
                                   -----+---------+---------+---------+-
Pooled StDev = 0.008255               0.0240    0.0320    0.0400    0.0480
```