EVALUATION OF THE EFFECTS OF FERTILIZERS ON THE PRODUCTIVITY OF SELECTED POTATO VARIETIES GROWN ON THE TAITA HILLS, KENYA

THOMAS GEOFFREY HARO

Thesis Submitted to the School of Science andTechnology in Partial Fulfillment of the Requirements for Master of Science Degree in Agricultural and Rural Development of Kenya Methodist University.

JULY , 2022

DECLARATION

This Thesis is my own original work and has not been submitted to any other University for any award.

Signature.. Date...24/10/2022...

Thomas Geoffrey Haro

Reg. No AGR-3-0289-1/2009

RECOMMENDATION:

This thesis has been submitted for examination with approval as the University supervisors.

1. Dr. David Mushimiyimana ....Date...24/10/2022...

Kenya Methodist University

2. Dr. Mwamburi Mcharo ....Date...24th/10/2022...

Taita Taveta University

DEDICATION

Dedicated to my wife Joyce Kwamboka, my children Patience and Emanuel and my Granddaughter Ella Maria who provided consistent support.

ACKNOWLEDGEMENT

I would like to express my sincere thanks to the many people who contributed to the success of this work. This work was accomplished under the guidance of Dr. David Mushimiyimana of Kenya Methodist University and Dr. Mwamburi Mcharo from the School of Agriculture, Earth and Environmental Sciences, Taita Taveta University. I appreciate their guidance with the field work and valuable time spent reading the thesis, and for all the valuable comments, advice and contributions to shape this work. Secondly, I thank the Government of Kenya through the Kenya Climate Smart Agriculture project (KCSAP) for sponsoring this research work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CIP	International Potato Centre
FAO	Food and Agricultutral Organization
GDP	Gross Domestic Product
GIZ	German Technical Cooperation(Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)
KARI	Kenya Agriculture Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
Kg	Kilogram
LAI	Leaf Area Index
M	Metre
MoA	Ministry of Agriculture
NPCK	National potato council of Kenya
NPK	Compound fertilizer NPK 17:17:17
PPM	Parts Per Million
PSDA	Promotion of Private Sector Development in Agriculture

ABSTRACT

Potato is an important food and cash crop whose yield is limited by biotic and abiotic factors. Of these factors, poor soil fertility and recommendation of nutrients matched with the respective suitable variety at specific agro ecological zone is rare as the case in the Taita Hills in Kenya. Thus, this study evaluated various NPK 17:17:17 fertilizer rates of 250, 500 and 750 kg ha^{-1} with or without cattle manure on four popular potato varieties (Tigoni, Shangi, Kenya Mpya and Dutch Robjin) for two seasons to establish the suitable high-yielding climate smart variety and fertilizer rate for the Taita Hills.The varieties indicated significant difference ($p<0.05$) in the yields in both seasons.The Shangi achieved high yields of 22 tons per hectare, compared to Kenya mpya that had the lowest tuber yield of 12 tons per hectare low. Generally, the potato grown in the long rains season of March to June performed better than the short rains season crop of October to December, thus long rains season being more suitable for higher tuber yields. The tuber yield was significantly different between the seasons ($p\leq 0.000$), among the varieties ($p \leq 0.000$), among the treatment ($p \leq 0.002$) and application of significantly increased the yields by 2.5 tonnes at 250 kg/ha, 3.4 tonnes at 500 and 4.3 tonnes at 500kg/ha. Shangi variety generally showed higher yields as compared to the other varieties. Shangi performed better than Dutch Robjin with about 6000kgha^{-1} and NPK application of 250kg, 500kg NPK increased the yields of potato by about 2500 and 3400 kg respectively as compared to no fertilizer. The application of 750kgha^{-1} NPK plus 7000 kgha^{-1} of cattle manure led to higher yield as compared to the application of 7000kgha^{-1} cattle manure alone, 250kgha^{-1} fertilizer alone or no fertilizer respectively. Hence, fertilizer use together with cattle manure practice is recommended for the Taita hills and Shangi variety is the most appropriate for the Taita hills.

CHAPTER ONE

1.0 INTRODUCTION

This chapter describes the background, problem statement, justification, objectives and hypothesis. The botany, ecological conditions, uses and development form the background information are also described.

1.1 Background

The potato (*Solanum tuberosum, L*) is a tuber in the solanaceae family that comprise of 90 genera of 2,800 species. It has two distinctive subspecies the *igena and tuberosum*.The *igena* sub species is diploid potato, adapted to short day conditions and is grown in Andes; while the *tuberosum*, is a tetraploid potato adapted to long day lengths (Anjum & Sahair, 2018).

Potato is a staple crop that is grown for both food and cash in the world (Devaux et al., 2014). Asia produces over half of the worlds potato, with China and Europe producing a third. In Africa, potato contributes about 7% of the global output, with Egypt and South Africa being the major producers (Devaux et al., 2014). Potato offers great promise in the East and Central African highlands despite huge yield fluctuations that have been experienced in the last two decades (Mburu et al., 2020).

In Kenya, potato can be grown all year round, however it is currently grown in only two seasons per year and the yields have been on a steady decline in recent years. This decline in yields, has been attributed to diseases, poor cropping practices , low quality seed, poor infrastructure and lack of an organized marketing system for the produce. (Mburu et al., 2020). Potato is a popular crop and competes for the same areas where maize is grown in the subtropical climates and at the high altitude areas where it is grown for horticulture and for food purpose (Okello et al., 2017).

The origin of potato lie in the southeast of Peru around the Andrean highlands, where it was first domesticated by the farmers near lake Titicaca, some 8000 years ago. In the 16th century, Spanish explorers brought potato to Europe from where its popularity has grown around the world. Potato is produced in 156 countries in the world and is also consumed by more than one billion people. It is an important food consumed after rice and wheat with millions of people in developing countries depending on potato for a living (International Potato Centre [CIP], 2022). The high nutrition value, high yields and production of good quality starch, flour, bread, soap, alcohol, weaning food and animal feed processes are some of the attributes that make potato important (CIP, 2022).

In Africa, the European missionaries and colonial administrators introduced potatoes and in Kenya, it was introduced by the the white settlers in the 19th century for food purposes and later for cash. Initially it was grown in Kiambu, Murang'a and Nyeri districts and is currently cultivated in the high altitude areas in Central, Rift Valley, Western, Nyanza, Eastern and Coast where the altitude ranges between 1,500 and 3,000 meters(Food and Agricultutral Organization [FAO], 2017). In Kenya, potato is currently grown by 800,000 small scale farmers on 161,000 hectares producing an estimated 1.5 million tons.This value chain is generating employment for an estimated 2.5 million (Kenya Plant Health Inspectorate Service [KEPHIS], 2016). The yields have however declined over the years and currently average between 9 – 10tons /ha, which is lower than the potential of 20 - 40 tons/ha (Mburu et al., 2018).

Potato contains starch and protein of high biological value, with substantial amounts of alkaline salts, soda, potash and vitamins A, B and C. It is important in the maintainance of the alkali reserves of the body and helps to prevent acidosis. (Rodriguez, 2011). The utilization of potatoes worldwide is changing from fresh produce to the processed potato products like the fries, chips, canned and mashed potatoes and ready meals (Lansink et al., 2018). Large amounts of potato are currently processed into special products of chips, crisps, puree and flour. They also provide a source of high grade starch for industry (Bradshaw & Ramsay, 2009). Potato is an important staple worldwide with a high nutrient price to ratio as compared to vegetables (Drewnowski & Rehm, 2013). Other key importance of potato as a feed, is that culled potatoes can be used to feed ruminants either fresh or whole tubers and also as chopped material. Potatoes can be used in silage with dry hay, maize stover, or straw.This will enhance the shelf-life of hay and also reduce choking hazards in livestock (Lardy et al., 2022).

1.2 Problem Statement

Potato yields have generally declined in Kenya and are currently less than half the amount obtained by some developed countries. Despite more acreage dedicated to the development of the crop, the annual production has continued to decline (Bradshaw & Ramsay, 2009). The major challenge facing potato production growth in Kenya is the continued low and declining of the yields.This situation has been occasioned by a myriad of challenges such as the use of poor quality and quantity of seed, climate change, inadequate extension services, pests and diseases menace and more importantly declining soil fertility, especially phosphorus (Akoto et al., 2020).

Generally, the soils in most potato growing areas in Kenya have low soil pH as aresult of the acidic nature of the parent rock. This together with the continued use of di-ammonium phosphate (DAP) fertilizer for the production of potato has further contributed to the lowering of the soil pH even further overtime.This together with the low soil fertility and use of fertilizer belowthe recommended rates has resulted in the soil nutrient imbalances. In order to alleviate this situation, there is urgent need to change the fertilizers used in potato production (Muthoni, 2016). Potato high nutrient content, crop adaptability to marginal environments, ease of cultivation, low cost and high yields per unit area contribute to the the underprivileged citizens in developing countries as their principal and most important source of food and income in the world (CIP, 2022).

1.3 Justification

Potato is an important food and cash crop that can contribute towards realization of Kenya Vision 2030 (KEPHIS, 2016). It has a high food production per unit area and grows faster compared to the other major food crops. It yields a crop with a food value of more four times compared to the hectarage of grain, twice the protein per hectare of wheat and is rich in protein, calcium and vitamin C with agood amino acid balance (VIB, 2019).In Kenya, it is mostly grown by smallholder farmers with less than 0.4 ha. These farmers produce upto 83% of the total national potato yields and is far below the potential yield .To enhance food security for the household, there is need for these farmers to improve their farm level productivity (Vossenberg et al., 2014). The farmers choice of the potato variety to grow is dictated by availability of potential markets, yield and the tastes of the consumers (Muthoni et al., 2014). According to (FAO, 2017), potato production has been on a decline in over the period 2011 to 2017 despite the increase in the crop acreage over the years. The clean planting material shortages have contributed to the spread of pests and diseases, low yields and poor quality harvest (Thiele et al., 2011).

1.4 Objectives

1.4.1 Broad objective.

To evaluate the effects of fertilizers on the productivity of selected potato varieties grown on the Taita hills, Kenya.

1.4.2 Specific objectives.

i. To evaluate selected potato varieties grown on the Taita hills for agronomic traits..
ii. To determine the effects of fertilizer treatments on the agronomic traits of selected potato varieties.
iii. To assess the effect of seasons on agronomic traits of selected potato varieties.

1.5 Research Hypotheses

i. The selected potato varieties are significantly different from each other in their agronomic traits.

ii. The fertilizer treatments have significantly different effects on the selected potato varieties.

iii. Cropping seasons have significantly different effects on the agronomic traits of the selected potato varieties.

CHAPTER TWO

2.0 LITERATURE REVIEW

The chapter presents the literature used in the study. This includes; general perspectives of the effects of fertilizer application in potato growing, the importance of nitrogen, phosphorus and potassium in production.

2.1 General Perspectives of Fertilizer Application on Potato.

Science based agriculture through the use of fertilizers to increase food production is important to enable feed the growing world population. Fertilizers have been used in the tropics to replenish the soil nutrients removed during crop production especially in cereals. The adoption of high yielding crop varieties and increase of crop biomass in nutrient poor soils has been done through the use of fertilizer (Scott & Suarez, 2012). Increasing crop yields through the use of high yielding varieties and the expansion of land area increase the demand for higher fertilizer application rates and additional nutrient uptake from both organic and inorganic sources are necessary to increase the crop biomass. However, there is no data on the relationship of the increase of biomas and the consumption of mineral fertilizer (Lusine et al., 2007).

Fertilizer is a material of natural or synthetic origin that is applied to the soil or plant tissues to supply plant nutrients for improved growth and yields. They replace the nutrients that crops mine from the soil. (Akoto et al., 2020). Excess phosphorus (P) is held and becomes unavailable to plants when it reacts with other elements, such as calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn), in the soil (Nwibo & Alimba, 2013). The application of fertilizer in potato production significantly increases the yields of potato plants also improves the agro-ecological condition of the soil. The use of organic manure for potato growing has shown impoved performance with the application of 35-40 tons/ha in sod-podzolic soils and 25-30tons /ha on gray podzolized soils. Organic manure, provide the plants with the basic nutrients for productivity and also contribute to the improvement of the soil structure the chemical composition. The use of cereal straw and green manure in growing potatoes in light gray podzolized soilsis an alternative source of fertilizer. The soil microbiological proceses are enhanced through the use of an organic fertilizer system where manure,straw of grain crops and green manure are applied. Compared to the mineral and organic mineral systems that reduce the cost of fertilizer use, improving the soil structure and giving high yield indicators, these practices are much more demanding (Okello et al., 2012).

The application of fertilizer provides fairly large amounts of important nutrients for living organisms. Nitrogen and phosphorus provide these critical elements for plant to grow and produce. This will increase potato production for smallholder farmers to sustain food production and ensure food security. (Prokop & Albert, 2008). Plant growth depends on nitrogen (N), it is essential in forming upto 1–4% of the plant dry matter. It is utilized as nitrate (NO_3^-) or ammonium (NH_4^+) compound from the soil. Nitrogen combines with compounds produced from carbohydrate metabolism to form amino acids and proteins.All the major processes of plant development and yield formation are also dependant on nitrogen (Scott et al., 2020). All the soil amendments either in sole or combined inorganic and organic fertilizers generally contribute to the improvement of soil fertility status and potato yield (Walelign, 2008).

Phosphorus stimulates root development, increased stalk and stem strength, enhanced flower establishment, seed production, uniform and earlier crop maturity (Muthoni et al., 2016). Volcanic soils, are typically deficient in phosphorus, however, potato growing can utilize organic manure at the start of the new rotation as it offers a good nutrient balance and preserves the structure of the soil. The use of chemical fertilizer depends on the level of available soil nutrients and this needs to be properly assesed according to the estimated crop harvest, the variety potential and the purpose of the harvest (Westra et al., 2020).

Adequate amounts of phosphorus(P), potassium (K) and nitrogen (N) fertilizers are required for ideal growing, production and the tuber quality of potatoes (Scott et al., 2013). Plant nutrients are mostly available at soil pH levels near 6.5, however when the soil pH goes down to pH levels of 5.0 - 5.2 , it is then necessary to use more fertilizer to achieve the required nutrient levels for the plants. The nutrient quality and quantities of animal manures can vary a lot, with the age and storage method being the two of the most important determinants of quality. No matter what the quality of manure, aged or composted are the best and there is still enormous value to build fertility in as far as providing the soil microbes with material they need (Anjum & Sahair, 2018).

Potatoes respond well to chemical fertilizers compared to other crops that grow well with animal manure, which may be contaminated with bacterial wilt and other serious diseases for potato. Hence, farmers need to refrain from the use of animal manure unless they are guaranteed it is uncontaminated. This raises an important challenge as to how their use relates to the recommended practice (Perry, 2002). From the foregoing, cultivation of potato are mainly governed by the availability of major nutrients required for the growth, development and yield. Nitrogen improves vegetative growth and invariably increases yield, tubers per plant and tuber size.It is the first limiting factor for potato production (Balemi, 2009).

2.2 Effect of Nitrogen on Potato Production.

The potato tubers increase in size with increasing nitrogen application. Increasing the level of N application, will increase the tuber yields up to a certain point. However, this will delay the tuber development with higher applications and the tubers end up with a watery texture, with low cooking quality (Okello, 2017). The foliage of plants with excessive nitrogen are very vulnerable to blight and this will lead to delays in potato setting and maturity (Shimelis, 2013).

2.3 Effect of Phosphorus on Potato Production

Phosphorus is an important component of the deoxyribonucleic acid (DNA), the store of hereditary material and ribonucleic acid (RNA), that guides protein production in both plants and animals. It is the second most often limiting plant nutrient and is essential for the general condition and robustness of plants (Najim, 2010). In potato production, phosphorus encourages early rooting as well as later maturity, harder skins, reduce tuber blight and increase dry matter content. Potato reuirement for phosphorus is high for optimum growth and yield, hence any deficiency will reduce the growth and yields considerably (Motawei, 2005). Acording to Bremner (2009), the improved application of phosphorus from 0 to 138 kg/ ha will also increase the height of potato plants from 34.00 to 64.00 cm, hence significantly increasing the marketable tuber yield per hectare (Khanal & Subedi, 2019).

2.4 Effect of Pottasium on Potato Production.

The potassium (K) element assists in preserving the plants osmotic potential, improves water uptake, root absorptivity, regulate ionic equilibriums, control plant stomata and stimulate enzymatic processes. It is important in value and produce qualities of potato including reducing sugar, Vitamin C content, specific gravity, shelf life and total produce (Park et al., 2018). It is essential as it has straight effects on the growing, yield and quality of potato tubers (Bekele, 2018). The potato plant growth and development rises with the increasing dose of potassium and therefore the plant canopy, stem width and leaf size (Baklawa et al., 2017). Potash rises tuber size,however additional may slightly decrease dry matter content. The usage of sulphate of potash instead of muriate of potash (chloride) will tends to rise tuber yield (Niragire et al., 2019).

2.5 Effect of Manure on Potato Production

The application of manure or fertilizer unaided cannot sustain soil fertility and crop yield over time, their blend is neccesary (Cortada, 2018). The usage of integrated organic manure and chemical fertilizers would be more favorable not only in providing better strength in production, but also in preserving the soil fertility position (Janssens et al, 2013). There is inadequate records on the growth, yield and nutrient content of agronomic crops treated with bio slurry, vermin compost and tricho compost available. Hence, there is need to develop a strong feasible and well-matched package of nutrient administration over the use of organic and inorganic sources for various crops grounded on scientific evidences, indigenous situations and economic feasibility to be done (Gouy et al., 2010).

Traditionally cattle manure is a basis of nutrients for many crops together with goat, sheep, and chicken manure (Hall, 2019). In the long term, management of nutrient cycles in crop and livestock systems will determine whether the balance becomes negative or positive (Goeminne et al., 2011). The main reason of providing organic manure in nutrient cycle arrangements is to break the complex inorganic nutritious additions into more simpler organic ones that can be absorbed and integrated by the plants easily. Manures having a low nutrient content have a outstanding result for a extended period of time and also increases the value of the soil (Faggian et al., 2012).

2.6 Effect of Climate on Potato Production

Potato is a cool period crop that develops best between 15°C and 18°C, with mean daily temperatures of 18-20°C and night time temperatures of less than 15°C . High temperatures delay, impede or even inhibit tuber initiation and reduce the yields by inhibiting starch synthesis in tubers. Generally water stress and rise in temperatures will lead to yield and tuber quality losses (Devaux et al., 2014). Potato grows well in areas with an annual rainfall of between 850 mm and 1,200 mm, and altitudes of between 1,500m and 2 800m above sea level, and cool to moderate temperatures (CKL Africa, 2022)

The response of the many different potato varietis to growing conditions is affected greatly by the environment and any environmental factor that is not idea will limit the plant's growth. The distribution of the environmental factors also affects where and when particular varieties are grown. In each gathering period, growing conditions which comprise temperature, day length, and growing period are environmental factors that affect plant growth, though they differ drastically. Thus, different varieties are adapted to environmental conditions (Najim, 2010).

2.7 Fertilzer Use in the Taita Hills

The area experiences a high rainfall in both the long and short rains seasons of March to June and October to December respectively (Mburu, 2018). The mean annual rainfall is over 1,200 mm in the hill masses. The area has average monthly temperature ranges from a minimum of 9.3 to 13.5 degrees to a maximum of 17.9 to 24.4 degrees. The dorminant soils in the Taita hills are Calcic Cambisol, Humic Cambisol and Eutric Regosols, which have moderate to high fertility. The soil pH ranges from extremely acid (4.18) to moderately alkaline 7.7. The soil organic matter rages from as low as 0.2% to 3.97% resulting to low water holding capacity and erosion (National Enviromental Management Authority[NEMA], 2009).There is limited use of inorganic fertilizer and majority of the farmers using farm yard manure (FYM) which is readily available with most households keep livestock which would encourage the use of manure (Jaetzold et al., 2009).

2.8 Characteristics of the Selected Potato Varieties.

Four (4) potato varieties, Tigoni, Shangi, Kenya Mpya and Dutch Robjin were selected because the are well known to the farmers and have been grown over the years. Farmers have a lot of experience in handling these vaieties. They have short to medium maturity and easy to prepare. Several Government programmes have also been supplying these varieties as they access them easily from the research station at KARI now reffered to as KALRO.

2.8.1 Tigoni

This is an erect tall potato variety that grows to a height slightly below 1metre (M). It is characterized by asolid stem and light green leaves and white flowers in colour. It performs well in the highland areas above 2300 m and matures between 3-4 months with a production of 35-45tons/ha. It is moderately resistant to late bright disease and has a tuber dormancy of 2.5 -3 months. Tigoni produces elongated egg-shaped tubers with a white smooth skin with apale yellow flesh and shallow eyes. This variety is for general table use and for production of frozen (National potato council of Kenya [NPCK], 2017).

2.8.2 Shangi

Shangi is a farmer selected variety that was introduced and distributed in the early 2000 before its official release (Lardy et al., 2022). It is one of the most popular varieties in Kenya that performs well and early maturing with high productivity, hence its popularity with farmers. This variety has short dormancy making it difficult to store with the aim of future processing. It is used for both industrial processing and home preparation. (Anjum & Sahair, 2018). Shangi is a medium tall variety slightly below 1 M in height, with semi-erect moderately strong stems with light green broad leaves and rosy flowers. It can be best grown at elevations of 1500 m and above. It is early maturing (≤ 3 months) with medium tuber yield of about 30-40 tons/ha. The tuber are oval in shape, plane cream skin, medium to deep eyes and a white flesh. The tuber inactivity is less than one month and is moderately vulnerable to late blight (NPCK, 2019).

2.8.3 Kenya Mpya

This is a tall semi erect potato variety that grows to a height of about 1m. It's characterized by having robust stems with bright green leaves of medium sized and white coloured flowers. It grows well in the medium to high altitude areas of 1400-3000 m and matures in 3-4 months with yields ranging from 35- 45 tonness per hectare. The tubers are oval in shape with smooth creamy skin and shallow and pink eyes. The tuber dormancy is 2.5-3 months long and is resistant to the late blight disease. This variety is suitable for making chips and for other table uses (NPCK, 2017).

2.8.4 Dutch Robjin

This is an erect medium tall Potato variety that grows to a height of about 0.7 m. It's characterized by strong stems with dark green leaves of medium size. The flowers are white with a light pink hue. Dutch Robijn does well in high altitudes of 1800-2600 masl. The maturity period for this variety is between 3-4 months. Its yield per hectare is less than 30 tonnes. The tuber dormancy lasts for 3.5- 4.5 months and moderately resistant to late blight. The tubers are round in shaped with red a rough, medium deep eyes and pale yellow flesh. This variety is very suitable for making crisps (NPCK, 2017).

CHAPTER THREE

2.0 RESEARCH METHODOLOGY

The chapter deals with the methodology of the study. It covers the site description, experimental design, data collection and, tools for data analysis.

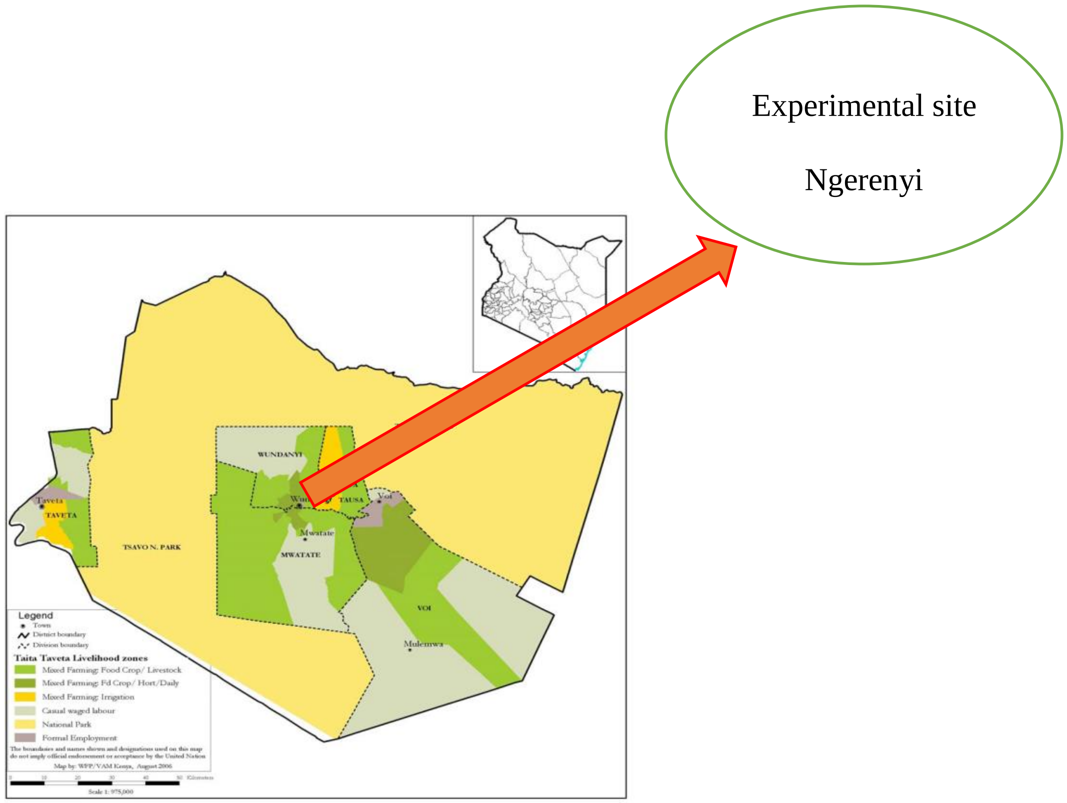
3.1 Site Description

3.1.1 The area of study

The Taita Hills area covers the high rainfall areas of Taita, Sagalla Kasighau and Mbololo hills which are approximately 100 km^2 in Taita Taveta County. They rise to a peak elevation of 2,208 metres above sea level at the Vuria hill in Taita. The hills cover an indigenous forest cloud that is a home to unique flora and fauna. The study was carriedout at the Taita Taveta University, School of Agriculture research farm, Kidaya-Ngerenyi campus shown in Figure 3.1 below. The campus is located at latitude -3.432475 and longitude 38.342788 at a mean altitude of 1600m.

Figure 3.1

Map showing the study area in Taita hills of Taita Taveta County, Kenya



3.2 Materials

3.2.1 Selected varieties

Four (4) potato varieties, Tigoni, Shangi, Kenya Mpya and Dutch Robjin were evaluated. These varieties were selected because the are well known to the farmers and have been grown over the years. Farmers have a lot of attachments towards these and demand for them whenever an opportunity arises.Several Government programmes have also been supplying these varieties as they access them easily from the research station at KARI now reffered to as KALRO.

3.2.2 Cattle manure

Cattle manure was obtained from the Taita ranches which has many livestocks units. It consist of the defacartions and urine of the livestock alone. The analysis of sample was carriedout to determine the actual composition for the macro and micro nutrients as showm in table 3.1 above indicate pH levels of 8.78, N- 1.05%, P- 1050 ppm and K-3.05 ppm.

3.2.3 Fertillizer NPK (17:17:17)

NPK 17:17:17 is a compound fertilizer that contains the three major plant nutrients of nitrogen, phosphorous and potassium in equal proportions. It is an all purpose fertilizer that provides all the nutrients the plant needs for healthy growth. This fertilizer is water soluble and is absorbed by the plant immediately.

3.3 Experimental Design

The experiment had three factors, fertilizer,varieties and seasons. Fertilizer treatments had eight levels and cultivar four levels.The seasons were two (long and short rains).The four selected potato varieties were treated with seven fertilizer levels and one control for two seasons. A total of thirty-two experimental units measuring 3m x3m replicated three times for two seasons. A randomized complete block design (RCBD) experiment was established and treatments assigned randomly using the random numbers generator.

3.4 Treatments and Treatment Combinations

The treatments involved planting the four selected test varieties with the different fertilizer as presented in Table 3.1.

Table 3.1

Treatment combinations

	Varieties			
Fertilizer	**Shangi**	**Tigoni**	**Kenya Mpya**	**Dutch Robjin**
Cattle manure	×	×	×	×
250 kg/ha NPK	×	×	×	×
500 kg/ha NPK	×	×	×	×
750 kg/ha NPK	×	×	×	×
250 kg/ha NPK + 7000 kg/ha cattle manure	×	×	×	×
500kg/ha NPK + 7000 kg/ha cattle manure	×	×	×	×
750 kg/ha NPK + 7000 kg/ha cattle manure	×	×	×	×
0 kg/ha NPK + 0 /ha cattle manure (control)	×	×	×	×

× - Indicating combination of that variety and the fertilizer rate.

3.5 Plot Layout

The experiment was conducted from 26th May to 28th August, 2021 for the longrain season and replicated from 24th August to 4th December, 2021 for the shortrain season. A total of thirty-two experimental units (plots) measuring 3m x3m were replicated three (3) times for two seasons (Figure 3.3). The blocks were spaced were spaced 1m apart while the plots spaced 0.5m path.

Figure 3. 2

Experimental block plot layout

14	15	17	8	3	26	2	12	16	11	31	21	10	24	27	9	32	30	4	22	18	29	28	23	6	1	7	5	20	13	19	25	BLOCK1
22	32	2	4	31	14	23	19	9	30	12	15	28	29	20	5	18	3	24	26	11	7	13	1	16	17	21	6	10	8	25	27	BLOCK2
24	31	27	6	4	18	32	15	10	8	25	2	16	14	28	11	12	1	13	21	7	29	20	5	9	19	3	17	26	23	22	30	BLOCK3

3.6 Field Activities

3.6.1 Land preparation

The land was ploughed to a depth of 20cm. This was to achieve a fine firm, weed free surface, and break the soil clods. Good soil aeration was achieved, soil drainage and decomposition of crop and organic matter.

3.6.2 Planting

Furrows of 8-12cm deep were dug and the tubers placed at a spacing of 75 cm from one row to the next. The tubers in each row were spaced at 30 cm from one tuber to the next tuber.

3.6.3 Fertilizer and manure application

The fertillizer NPK was applied at three levels: 250 $kgha^{-1}$, 500 $kgha^{-1}$ and 750 $kgha^{-1}$ each at planting. To prevent scorching of the sprouts the fertilizer was thoroughly mixed with the soil. Well decomposed cattle manure at a rate of 7000 kg per hectare was applied selectively either alone or mixed with the different levels of NPK depending on the assigned treatment.

3.6.4 Ridging/earthing-up and weeding

Ridging was done during weeding when the plants reached a height of between 10-15 cm and repeated two times during the crop season. The final ridge was about 25cm high. This process allowed the stolons to develop tubers and also prevent the tubers from turning green. To save on the cost of production, ridging was combined together with weeding. During weeding unwanted plants debris in the potato field was removed.

3.7 Data Collection

3.7.1 Germination percentage (%)

After four weeks of planting, the number of plants that emerged were counted and data recorded. This is the time when all the seed potato is expected to have germinated.The total plants that germinated was divided by the number of seeds planted and the parameter was expressed as a percentage (%).

3.7.2 Leaf area index (LAI)

One leaf is harvested from the mid quadrant of four randomly selected of each ridge. The length and the width are measured. The product of the length and width is multiplied with a constant 0.75 to get the LAI.

3.7.3 Plant height (cm)

During the seventh week after planting and when plant growth is at its maximum, four plants were randomly selected per ridge from each experimental unit and using a meter rule, the plant height was measured.

3.7.4 Number of stems per plant

Counting of the number of stems was done during day 7, 14, 21, 28 and 35 after emergence (DAE). Four plants were randomly selected per ridge of each experimental unit and the number of stems were counted and recorded as the number of stems per plant. It is easier to count the stems per plant at this stage as the leafy vegetation is usually less dense.

3.7.5 Plant/canopy cover (m^2)

The plant cover is also denoted as soil cover, this is the ground surface area that is covered by the plant vegetation. The area of four randomly selected plants per ridge in each experimental unit was calculated using the length and width of the plant shade on the ground.This was on 70th day after emergence.The average canopy area cover is expressed as a percentage .

3.7.6 Period (in days) to 50 % flowering

During the rapid growth period 10 plants in the different experimental units are randomly selected and every day plants, which make flowers were counted. The day 5 plants flower from the 10 plants flowers, is estimated as 50% flowering (Devaux et al., 2014). The number of days it takes for 50% the plants to flower from planting was recorded. Flowering was determined from the appearance of the flower buds.

3.7.7 Period in days to reach 95 % maturity (wilting)

The wilting of haulms characterize physiological maturity. The number of days taken to achieve 95% physiological maturity is when the leaves dry.

3.7.8 Tuber fresh weight (TFW)

The total freshly harvested tubers for each experimental unit were wet weighed per plot after gathering all grades of the tubers.These were converted into tons per hectare and recorded at harvest.

3.7.9 Average number of tubers per plant

The actual number of tubers from ten mature plants randomly selected at harvest were counted and the average calculated.This was counted physically after pulling out the tubers (at harvesting time).

3.7.10 Total tuber yield (kg)

After harvesting the tubers were graded in to five categories from each plot based on the tuber size (charts ≤ 56mm, small 56 -63.9, medium 64 -5.9, large76- 83.9 and extra large >84 mm) according to the explanatory guide: as shown in Table 3.4 below.

Table 3.2

Grades of the potato tubers

Category	Tuber diameter (mm)
Charts	<56
Small	56 – 63.9
Medium	64 – 75.9
Large	76- 83.9
Extra large	>84

Source: Seed Potato Classification Scheme and Explanatory Guide Approved Stock Scheme (2016)

3.7.11 Number of tubers.

After harvesting the number of tubers for each plot in all the replications were counted and the number of tubers recorded in each class.

3.7.12 Dry matter content.

Five fresh tubers for each plot in all the replications were sampled and tuber dry matter content (%) was measured. According to Williams and Woodbury (1968), the tubers were harvested, weighed, chopped and dried in an oven at 75^{o}C and then the dry matter content is calculated as follows.

$$\%\, Dry\, matter = \frac{Weight\ of\ dried\ sample(g)x100\%}{Weight\ of\ fresh\ sample}$$

3.8 Data Analysis

A three-way ANOVA was conducted on the data to compare potato yields on 4 varieties in two seasons under eight fertilizer treatments. The ANOVA test was also based on the assumptions of normality, homogeneity and independence (Mburu et al., 2020). Therefore, before conducting the ANOVA test, data were examined to determine whether these assumptions are satisfied, and if not, resolution done using acceptable statistical procedures (Rodriguez, 2011; Lansink et al., 2018). Alpha level was set a priori at α = 0.05 and the results of the analysis show the degrees of freedom (*df*), sum of square (*SS*), mean square (*MS*), *F*- Test (*F*), significance level (*p*) and effect size.

A significance level less than the alpha level ($p < \alpha$) would imply significant differences of yield of potato varieties, over season and under the 8 fertilizer treatment, and a significant level greater than the alpha ($p > \alpha$) would imply otherwise. Three-way ANOVA was chosen over independent t-test because it is appropriate in explaining a continuous variable with two or more categorical variables (Bradshaw & Ramsay, 2009).

In addition, Drewnowski and Rehm (2013) noted that ANOVA tests avoids potential risks of committing type I error. Akoto et al. (2020) emphasized that for ANOVA to be conducted, the dependent variable must be quantitative and the independent variable categorical with more than two levels. Vossenberg et al. (2014) further noted that the levels of the independent variables are assessed simultaneously thereby creating the condition of comparison. As a matter of fact, changes of the dependent variables are influenced by changes of the independent variables. In this study, cultivars' yields were collected as continuous (dependent) variable while the season and treatments categorical independent variables. Data collected on agronomic parameters was summarized in exel tables and analysed using the SPSS software version 20. The data was presented in graphs and discussed in the narrative. The Analysis of variance (ANOVA) was done at 95% confidence level ($p < 0.05$) and the means separated by Fisher's Least Significant Difference (LSD). Fertilizer rates, manure and variety interactions were fixed factors while the blocks were random factors.

CHAPTER FOUR

4.0 RESULTS AND DISCUSIONS

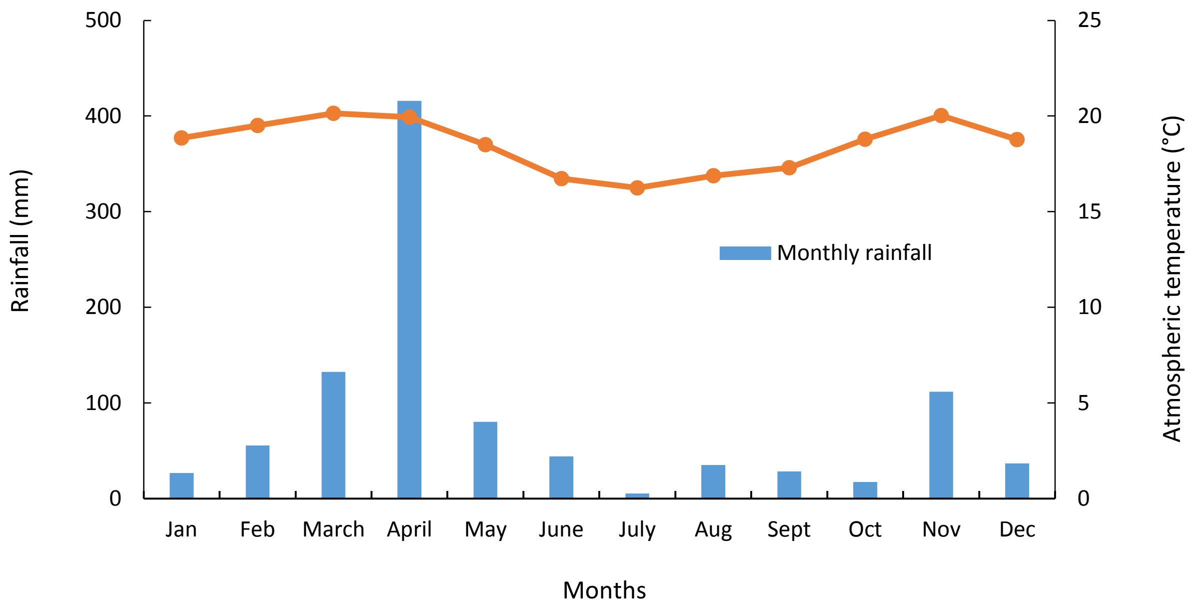
This chapter deals with the presentation of the results of the experiment and discusions. The data include growth parameters that include: germination, the leaf area index, the plant height, the stems per plant, the plant cover and flowering. The potato yield parameters include: The fresh weight of the tubers harvested, grades and number of the tubers.These parameters have been analysed and presented in figures and tables.

4.1 Rainfall and Temperatures

During the study period the rainfall and temperatures for the year were observed as shown in Figure 4.1 below.The total rainfall received of 988.1mm which is within the potato growing requirements range of between 850-1200mm per annum with the month of April receiving higher amounts of 415mm. The temperatures also ranged between 16 ^{0}C in July being the coldest month to 20^{0} C in November which was also the hottest month in the year.

Figure 4.1

Monthly rainfall and average atmospheric temperature (January-December, 2021 – Wundanyi station in the Taita hills).



4.2 Soil and Cattle Manure Analysis.

Soil sampling for this experiment was done randomly from a depth of between 0-30 cm at the site of the experiment. Five samples were taken in a x-pattern, mixed carefully, air dried and processed using a 2-mm sieve. The sample was analysed for the total N, P, K, Ca, Mg, Fe, Mn, Cu, Zn and organic carbon. Total N was analysed using the Kjeldahl method (Motawei, 2005) and total P, K, Ca, Mg, Fe, Mn, Cu and Zn using the Mehlich 3 extraction (Bremner, 2009). Soil pH was measured in a water paste at a 1:2 ratio of soil to water and the results are presented in Table 4.1 below. The Cattle manure was obtained from the Taita ranches which has many livestocks units. It consist of the defacartions and urine of the livestock alone. Analysis of samples was done to determine the actual composition of the manure both for the macro and micro nutrients as showm in table 4.1 indicate pH levels of 8.78, N- 1.05%, P- 1050 ppm and K-3.05 ppm.

Table 4.1

Soil analysis results at the study site.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	500.521	1	500.521	54.380	.000
VARIETY	132.688	3	44.229	4.805	.003
BLOCK	95.948	2	47.974	5.212	.006
Treatments	59.479	7	8.497	.923	.490
Error	1638.344	178	9.204		
Corrected Total	2426.979	191			

a. R Squared = .325 (Adjusted R Squared = .276)

Source of soil nutrient critical levels for potato (Muthoni, 2016)

4.3 Plant Germination/ Sprouting.

The data collected is summarized and presented as shown on Figure 4.2 . Germination of the selected varieties was different with the different treatments. Dutch robjin had the higher germiation rate compared to Shangi, Tigoni and Kenya Mpya respectively. However closer analysis indicated that germination of all potato varieties achieved >60%.The ANOVA results indicated that the germination was significantly different ($p \leq$

0.000) between seasons and among varieties ($p \leq 0.000$) as shown in table 4.3 . The post hoc on the means for the different varieties, confirmed that Dutch robjin performed better than Kenya mpya with about 15%. Shangi and Tigoni also performed better compared to Kenya Mpya with 12% and 10% respectively . The variance in germination percentage by seasons could have been attributed to the soil moisture as indicated by the performance rains during the seasons Figure 4.1 above. This observation agrees with Thiele et al. (2011) assertion that during germination, seeds absorb water when exposed to moisture, which triggers the start of the physiological processes of germination (Nwibo & Alimba, 2013).

Seed preparation is an effective system that increases the seed germination and plant development. This will increase production under different ecological conditions and stresses (Scott & Suarez, 2012). This agrees with the assertion of Balemi (2009) that seed populations tend to germinate in a characteristic pattern over time. This agrees with Akoto et al. (2020) that increased number of actively sprouting eyes is a subject to the potato variety (Lusine et al., 2007).

Figure 4.2

The effect of fertilizer on germination of the selected potato varieties.

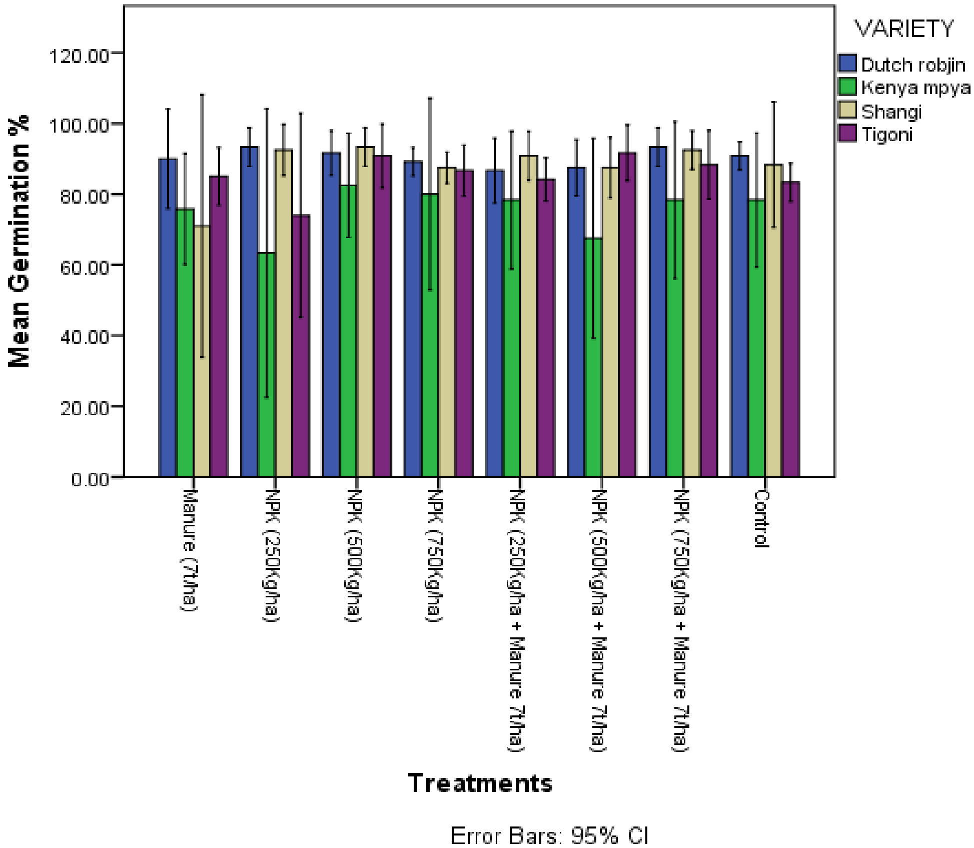


Table 4.2

ANOVA The effect of fertilizer on germination of the selected potato varieties in percentage (%)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	3209.505	1	3209.505	14.294	.000
BLOCK	551.823	2	275.911	1.229	.295
VARIETY	6087.516	3	2029.172	9.037	.000
Treatments	1720.995	7	245.856	1.095	.369
VARIETY * Treatments	3857.943	21	183.712	.818	.695
Error	35252.839	157	224.540		
Corrected Total	50680.620	191			

a. R Squared = .304 (Adjusted R Squared = .154)

Table 4.3

LSD for the effect of fertilizer on germination.

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		14.7917*	2.3750	4.8125
Kenya mpya			-12.4167*	-9.9792*
Shangi				2.4375
Tigoni				

The means observed.

Term error is the Mean Square(Error) = 224.540.

*. The mean is significant at the 0.05 level.

4.4 Leaf Area Index (LAI)

The data collected was summarized as shown in figure 4.3 . Dutch Robjin and Kenya Mpya had higher LAI compared to Shangi and Tigoni.The ANOVA however, indicated significant difference between season ($p \leq 0.035$) and treatment ($p \leq 0.030$) as shown in Table 4.4 . The LSD also confirmed that Dutch Robjin had higher LAI compared to Shangi and Tigoni at 3.48 and 3.31 respectively as shown in Table 4.5 .This observation corroborates with Perry (2002) where leaf area indices increased with the application of additional NPK compared with no application.These results confirm that, achieving the maximum leaf area indices requires additional plant nutrients supply.These findings also concur with earlier reports that, application of higher doses of N fertilizer, increased the leaf area index and delayed leaf senescence (Okello et al., 2012).

Figure 4.3

The Effects of fertilizer treatment on Leaf Area Index (LAI).

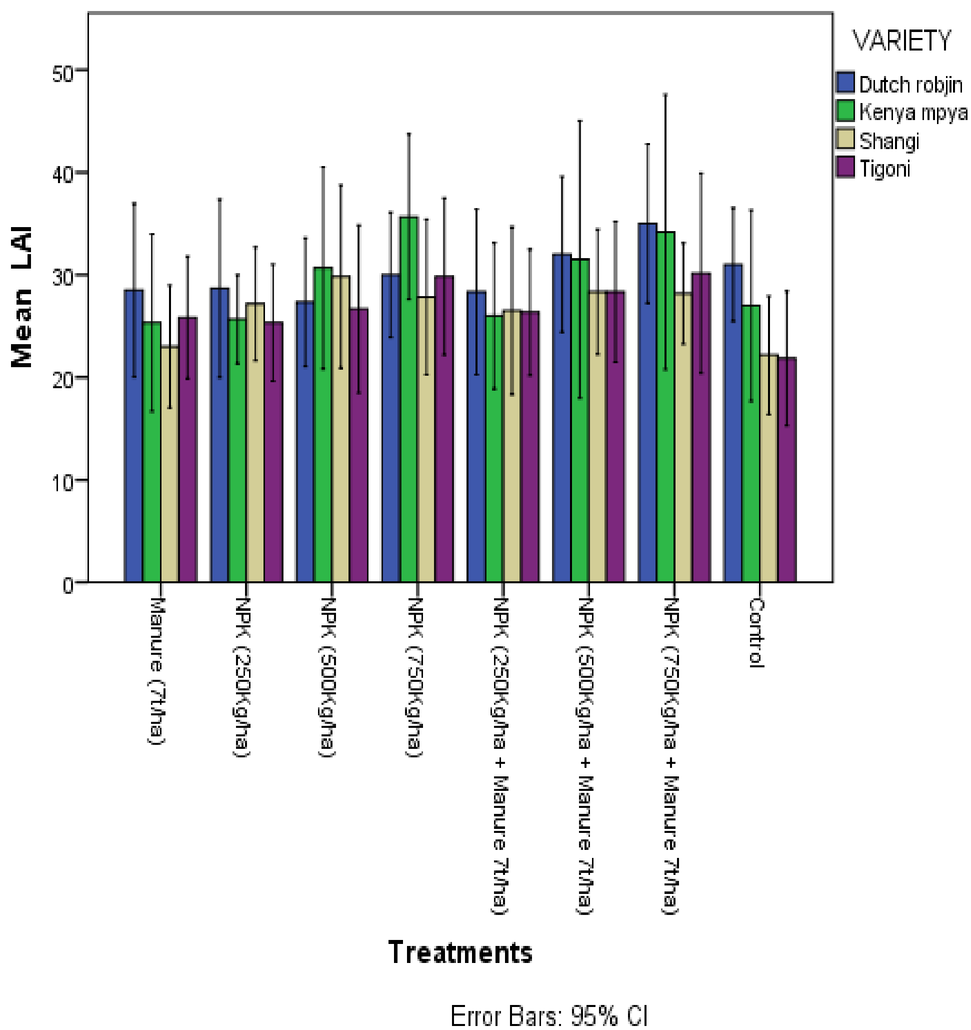


Table 4.4

ANOVA on the effects of fertilizer on the leaf area index.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
VARIETY	468.849	3	156.283	2.503	.062
Treatments	1005.703	7	143.672	2.301	.030
SEASON	282.755	1	282.755	4.529	.035
VARIETY * Treatments	559.109	21	26.624	.426	.987
VARIETY * SEASON	220.932	3	73.644	1.180	.320
Treatments * SEASON	146.120	7	20.874	.334	.937
VARIETY * Treatments * SEASON	329.693	21	15.700	.251	1.000
Error	7991.333	128	62.432		
Corrected Total	11004.495	191			

a. R Squared = .274 (Adjusted R Squared = -.084)

Table 4.5

LSD test for the effect of treatment on the leaf area index (LAI).

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		.60	3.48*	3.31*
Kenya mpya			2.88	2.71
Shangi				-.17
Tigoni				

The means observed.
Term error is the Mean Square(Error) = 56.041.
*. The mean is significantly different at the 0.05 level.

4.5 Plant Height (cm)

The plant height indicates the overall growth of the plant.It is predictive of the final yield and biomass, hence an important morphological and developmental phenotype (Prokop & Albert, 2008). The height was calculated and the data presented in Figure 4.4 . Shangi had the tallest plants among the varieties, followed by Tigoni and Kenya Mpya, whereas, Dutch Robjin had the shortest plants. Further more, not applying any NPK or cattle manure to potato led to shorter potato plants. Shangi and Tigoni grew taller than Dutch Robjin and Kenya mpya at all fertilizer levels. The ANOVA conducted indicated significant difference between the seasons ($p \leq 0.010$), among the varieties ($p \leq 0.000$) and fertilizer treatments ($p \leq 0.001$) as shown in table 4.6. The potato varieties that received 500 kg/ha NPK and cattle manure were significantly taller, although, this was not different from those that received 750 kg/ha NPK or 750 kg/ha NPK plus cattle manure. The LSD test confirmed that, Kenya Mpya was significantly taller to Dutch Robjin by 5.27cm, while Shangi is 11.83cm taller than Dutch Robjin and 6.56 cm taller than Kenya Mpya.Tigoni on the other hand was 9.63 cm taller than Dutch Robjin and 4.35 cm than Kenya Mpya as shown in Table 4.7 below.

The stature of a plant determines its absorption of resources, such as light interception and radiation, (Scott et al., 2020) confirmed that, the more a plant towers, it improves photosynthesis if other components required for growth are optimum. This could have been the case for Shangi. In addition, Walelign (2008) observed that shading reduced photosynthesis, therefore Shangi towering above other plants edged out the competition possibly promoting photosynthesis. Westra et al. (2020) in a study with Juniper forests, confirmed that increasing doses of NPK fertilizer increased the growth and nutrient uptake of trees compared to low doses and (Scott, 2013) confirmed that increased application of nitrogen to potato also increased the plant height.

Figure 4.4

Effect of fertilizer treatments on the stem height (cm)

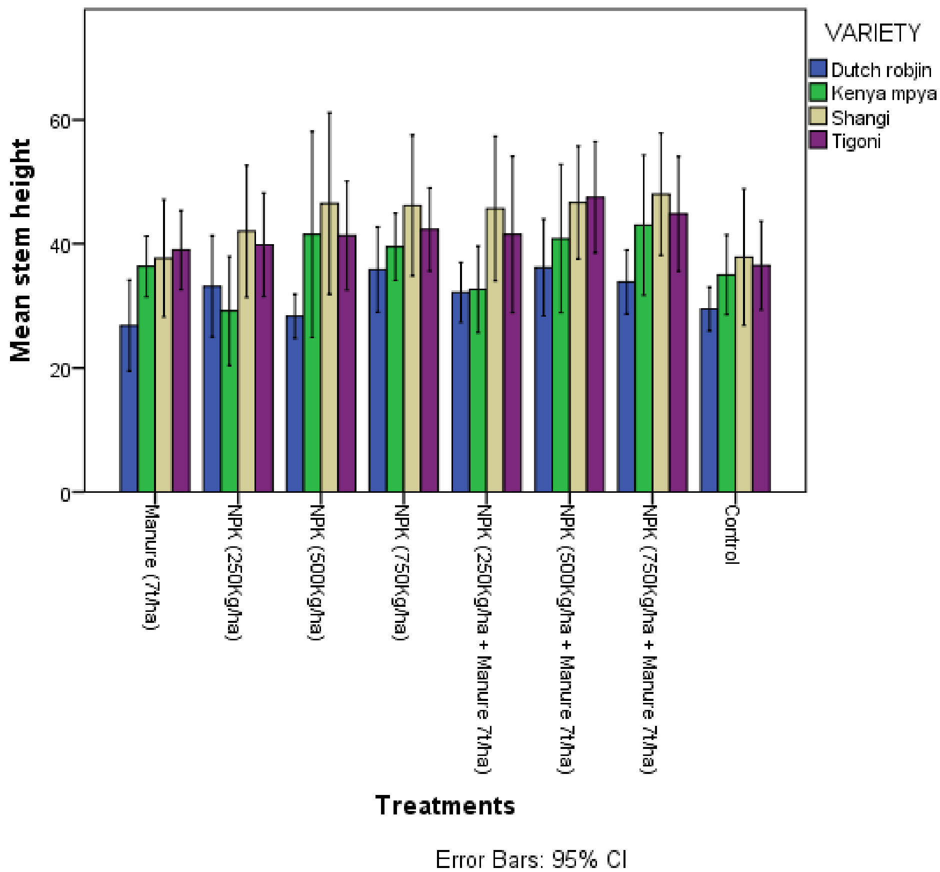


Table 4.6

ANOVA effect on the effect of fertilizer treatments on stem height.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	435.005	1	435.005	6.763	.010
VARIETY	3928.224	3	1309.408	20.358	.000
BLOCK	1093.260	2	546.630	8.499	.000
Treatments	1767.536	7	252.505	3.926	.001
Error	11448.969	178	64.320		
Corrected Total	18672.995	191			

a. R Squared = .387 (Adjusted R Squared = .342)

Table 4.7

LSD test for the effect of variety on the stem height.

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		-5.27*	-11.83*	-9.63*
Kenya mpya			-6.56*	-4.35*
Shangi				6.56*
Tigoni				

The means observed.

Term error is the Mean Square(Error) = 64.320.

*. The mean is significantly different at the 0.05 level.

4.6 Number of Stems per Plant

High number of stems will lead to ahigher number of tubers per plant. This will reduce the amout of carbohydrate that will be available for each tuber, hence will result in to reduced tuber sizes (Devaux et al., 2014).The results indicate the average number of stems per plant is shown in the Figure 4.5. Dutch Robjin had higher numbersof stems per plant with all the fertilizer treatments, followed by Shangi and Tigoni. Kenya mpya had the lowest stem numbers per plant. The number of stems may have been affected by the internal inherent characteristics of the variety including the age of the seed after harvesting.

The ANOVA indicate that there was a significant difference on number of stems as aresult of the season ($p \leq 0.000$) and variety ($p \leq 0.000$) as shown in Table 4.8 below. The LSD conducted indicated that Dutch Robjin had higher number of stems compared to Shangi,Tigoni and Kenya Mpya. Dutch Robjin had 4.4 morestems compared to Kenya Mpya, 2.54 more than Shangi and 2.96 stems more than Tigoni. Shangi also had 1.85 more stems than Kenya Mpya as shown in Table 4.9. The physiological age of the tuber main factor that affects stem number,since the seed potato age is either determined by the chronological or physiological attributes. The chronological age is determined by the number of days fom harvest while physiological age will refer to the internal age of the seed as affected by biochemical changes within the tuber (Faggian et al., 2012). Generally, older seed result in earlier emergence and increased number of stems (Goeminne et al., 2011).

The yield potential theory states that, the possible yield is not fully achieved in the natural production conditions. This is because biotic and abiotic influences affect with the potato crop and negatively upsets the plant growth and tuber development (Okello, 2017). The shoot structure of potato is a mixture of stems with terminal inflorescences and shoot development. It is measured in terms of stem production, while the stem growth is measured in terms of leaf and flower primordia production per stem.These are roles of the rates and the periods of primordia commencement. (Hall, 2019).

Figure 4.5

The effects of fertilizer treatments on the number of stems(no)

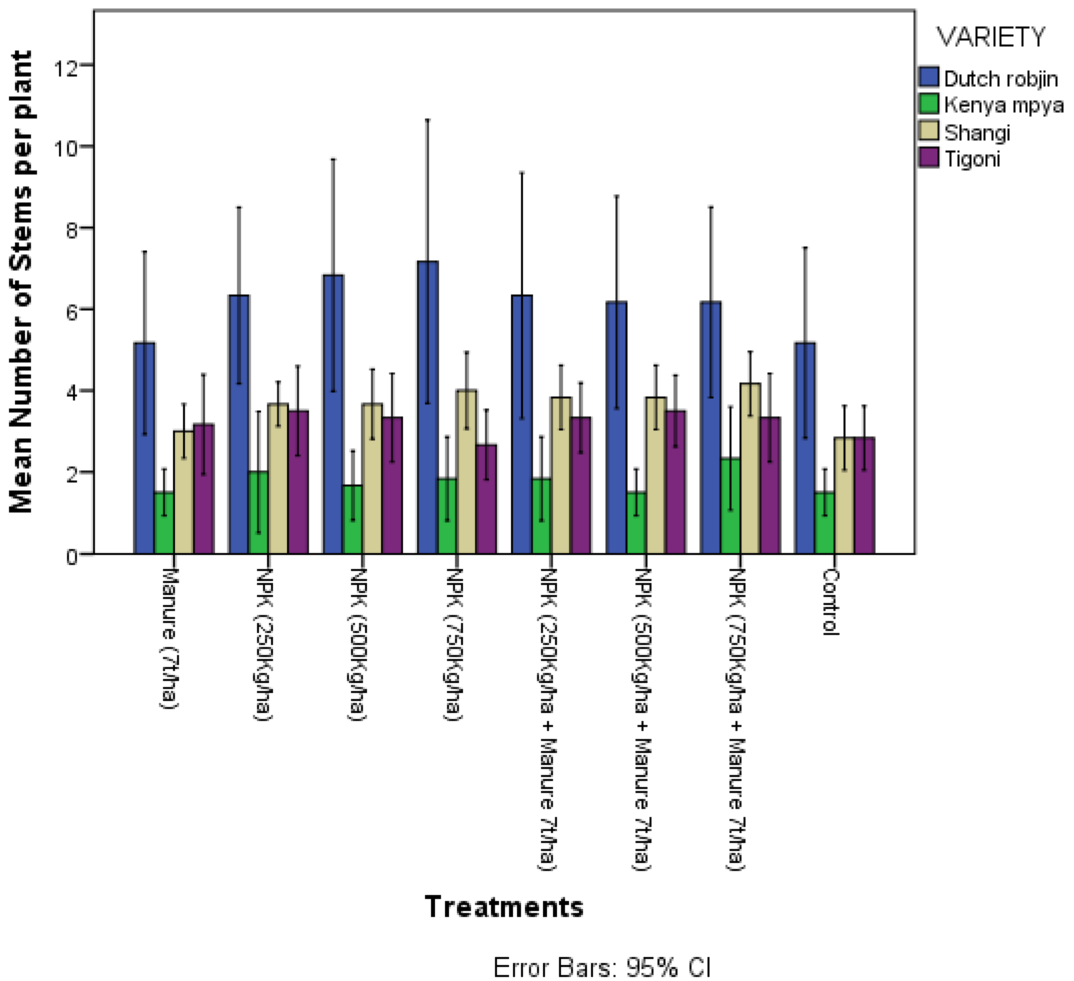


Table 4.8

ANOVA effects of fertilizer treatments on the number of stems.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	53.130	1	53.130	30.892	.000
VARIETY	482.557	3	160.852	93.526	.000
BLOCK	8.885	2	4.443	2.583	.078
Treatments	20.161	7	2.880	1.675	.118
Error	306.135	178	1.720		
Corrected Total	870.870	191			

a. R Squared = .648 (Adjusted R Squared = .623)

Table 4.9

LSD test on the effect of fertilizer treatment on the number of stems.

	Dutch Robjin	Kenya Mpya	Shangi	Tigoni
Dutch robjin		4.40*	2.54*	2.96*
Kenya mpya			-1.85*	-1.44*
Shangi				.42
Tigoni				

Based on observed means. The error term is Mean Square(Error) = 1.720.

*. The mean difference is significant at the 0.05 level.

4.7 Soil /Plant Cover (m^2)

Plant cover is the surface area of the plant when projected on the surface of the ground (Gouy et al., 2010). It is the plant vegetation surface cover from above. The row width covered by the crop is measured using a ruler on day 70 after planting and the average is expressed as a percentage as shown in Figure 4.5 . The ANOVA indicated that the potato canopy coverage of the soils was significantly different between the season ($p \leq 0.000$) and among the varieties ($p \leq 0.018$) Table 4.10. The LSD test confirmed that Shangi had a higher leaf cover (6.44) compared to Dutch Robjin and Kenya Mpya respectively .This optimal atmospheric temperature of 20-24 °C could have increased photosynthesis in Shangi compared to Dutch Robjin and Kenya Mpya Table 4.11 . Janssens (2013) study confirms the canopy growth with application of fertilizer. Also, canopy growth Shimelis (2013) supports this suggestion of canopy growth and taller plants.

Figure 4.6

Effect of the fertilizer treatments on the soil/plant cover.

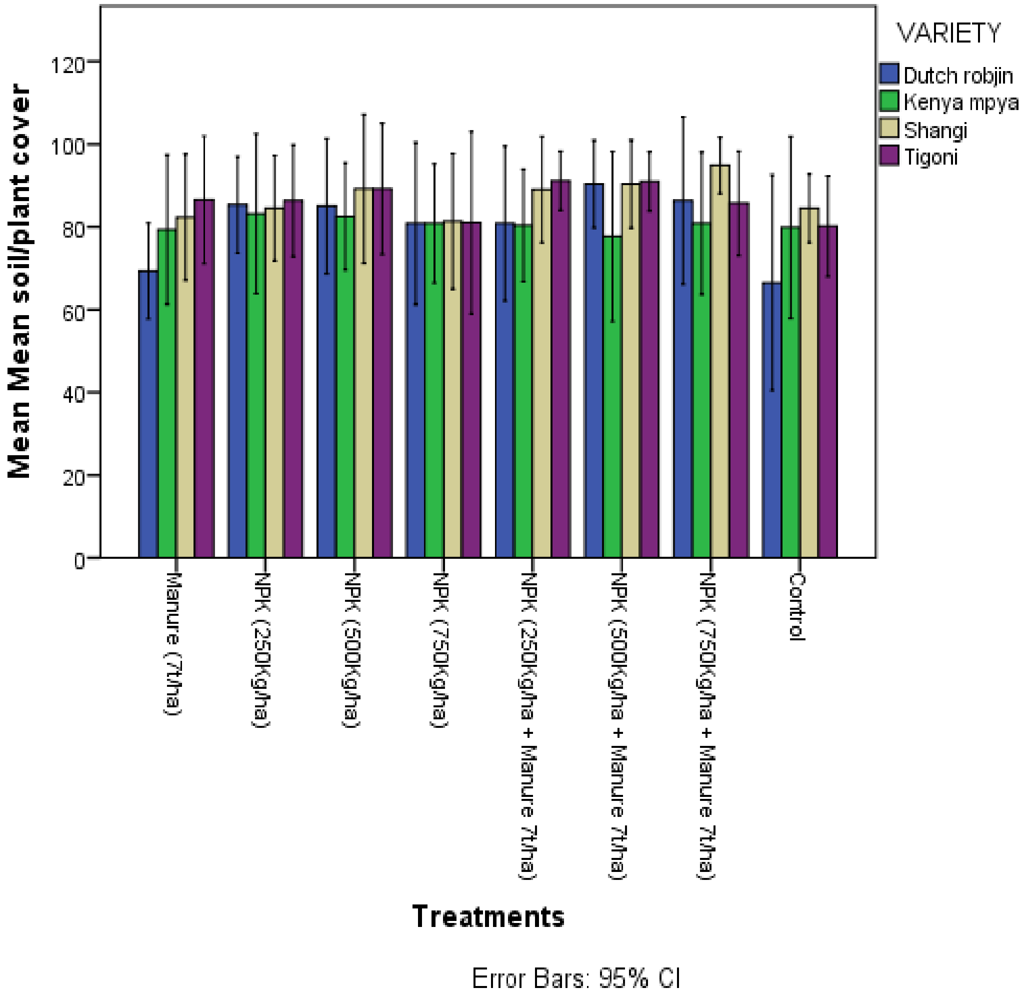


Table 4.10

ANOVA table for the effect of fertilizer on the soil/plant cover

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	3763.021	1	3763.021	21.439	.000
VARIETY	1810.125	3	603.375	3.438	.018
BLOCK	3127.594	2	1563.797	8.909	.000
Treatments	2315.083	7	330.726	1.884	.075
Error	31243.177	178	175.523		
Corrected Total	42259.000	191			

a. R Squared = .261 (Adjusted R Squared = .207)

Table 4.11

LSD test for the effect of fertilizer treatments on the soil/plant cover.

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		.00	-6.44*	-5.81
Kenya mpya			-6.44*	-5.81
Shangi				.63
Tigoni				

The observed means. Term error is the Mean Square (Error) = 175.523.

*. The mean is significantly different at the 0.05 level..

4.8 Period (in days) to 50 % Flowering

It is determined by the apresence of flower buds on the stems from a single tuber as shown in Figure 4.6. The period to 50% flowering was not very different from the different treatments. The effects of the treatments on the period to 50% flowering were not significantly different from each other as shown in Table 4.12. However, there was some significant difference in seasons ($p \leq 0.033$). This could have been attributed to the warmer tempratures in season two compared to season one. The potato growth and development is sensitive to ecological effects. In warm temperature and long day lengths the quantity of leaves, flower primordia per stem and the number of stems per shoot will increase by delaying stem production and primordia growth (Park et al., 2018). The flower development will follow the full development of theflower buds (Khanal & Subedi, 2019).

Figure 4.7

The Effects of the fertilizer treatment on the period to 50% flowering.

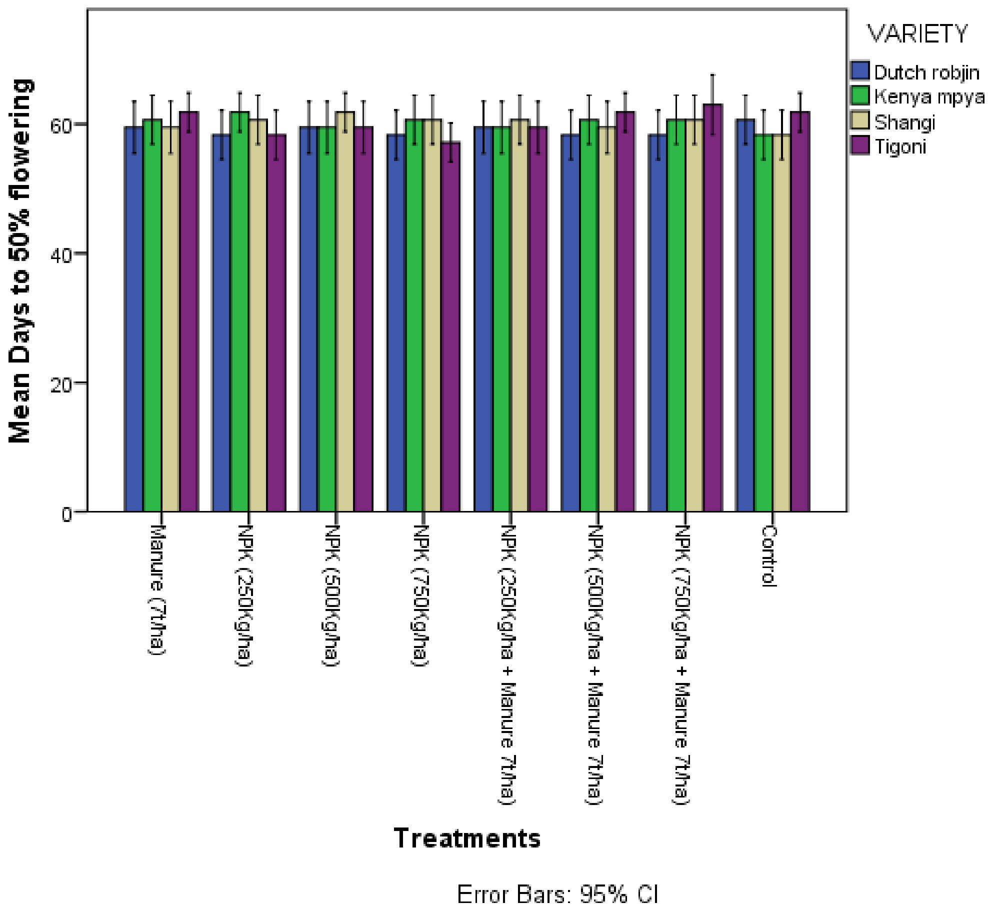


Table 4.12

ANOVA table for the effects of fertilizer treatments to the period to 50% flowering.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	57.422	1	57.422	4.624	.033
VARIETY	53.849	3	17.950	1.445	.231
BLOCK	52.573	2	26.286	2.117	.123
Treatments	32.411	7	4.630	.373	.917
Error	2210.615	178	12.419		
Corrected Total	2406.870	191			

a. R Squared = .082 (Adjusted R Squared = .014)

4.9 Period in Days to 95 % Maturity (Wilting)

Potato varieties are categorized depending on the number of days they require to come to maturity. Potatoes are grown between is 16-21°C which is ideal while temperatures that are greater than 26°C are usually too warm. The early maturing varieties usually require 75 to 90 days to harvest, medium varieties require 90 to 135 and late maturing varieties 135 to 160 days to reach harvest (Najim, 2010). As plants mature, plant parts begin to senesce, this is the last stage of plant development and is shown by discolouration and drying out of plant parts (Cortada, 2018). Physiological maturity is the wilting of haulms of the potato plants. This was observed from planting untill the leaves are 95% dry, as shown in the Figure 4.7. There was not much variation in the period to maturity for the different varieties. Most of the varieties matured in 70 day after plating despite the different fertilizer treatments applied. However, the ANOVA results indicated significance in the seasons ($p \leq 0.000$) as shown in Table 4.13. This may have been as a result of the effect of rain and temperatures during the season.

Figure 4.8

The effects of fertilizer treatment on the period to 95% plant maturity.

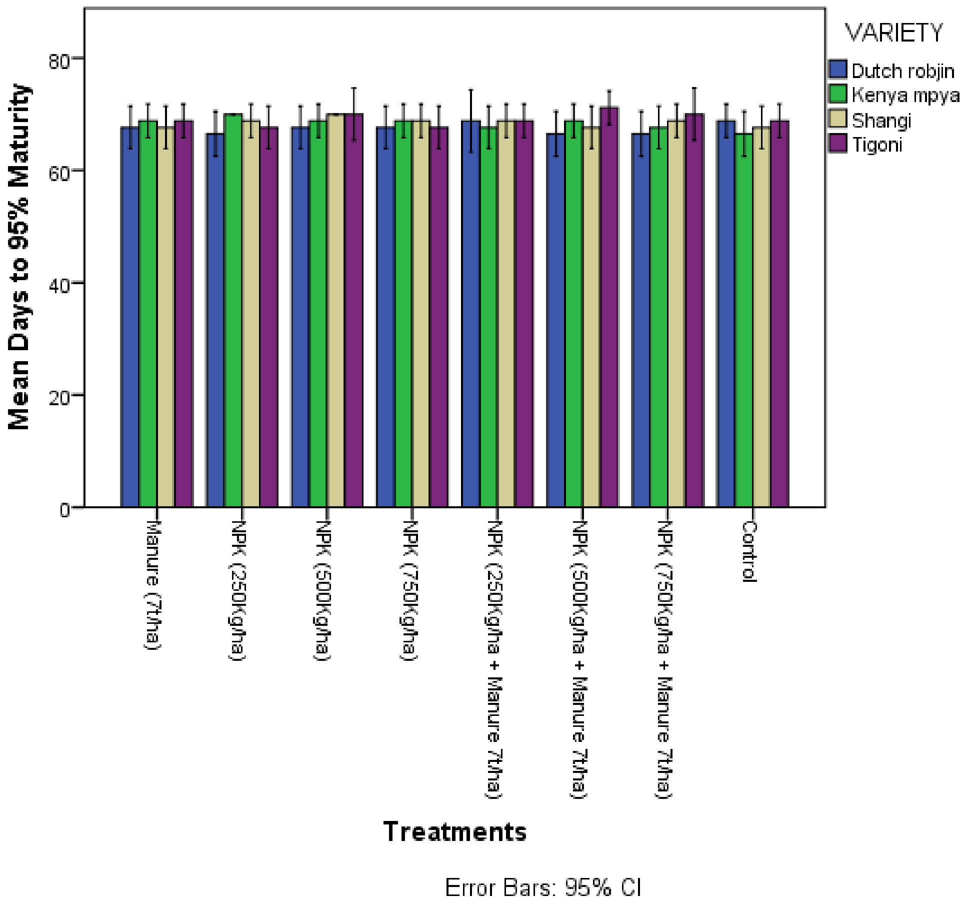


Table 4.13

ANOVA table on the effects of fertilizer treatment on the period to 95% maturity.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	494.083	1	494.083	60.225	.000
VARIETY	63.292	3	21.097	2.572	.056
BLOCK	15.823	2	7.911	.964	.383
Treatments	20.417	7	2.917	.356	.927
Error	1460.302	178	8.204		
Corrected Total	2053.917	191			

a. R Squared = .289 (Adjusted R Squared = .237)

4.10 The Total Fresh Tuber Yield

The total fresh tuber yields were measured on the harvested tubers from each plot and the results were extrapolated and recorded per hectare.The data was summarized in the Figure 4.8. The yield of potato was significantly different between the seasons ($p \leq 0.000$), among the varieties ($p \leq 0.000$) , among the treatment ($p \leq 0.002$) as shown in Table 4.14 . The results from the LSD show that application of NPK significantly increased the yields by 2.5 tonnes at 250 kg/ha NPK, 3.4 tonnes at 500kg/ha and 4.3 tonnes at 500kg/ha NPK.The precipitation in the long rain season was generally higher that the shortrain season which could have attributed to the difference in the yield. The Shangi variety generally showed higher yields as compared to the other varieties. Shangi performed better than Dutch

Robjin with about 6000kg per hectare as shown in Table 4.15 . Multiple comparisons of the means on NPK showed significant difference in yield at the different level of application.The difference of yield for application of 250kg NPK improved the yield by about 2500 Kg compared with no application of NPK.While the application of fertilizer at 500kg NPK increased the yield by upto 3400 kg per hectare Table 16 shown below. Nitrogenous fertilizer application to potatoes before tuber initiation will increase the tuber numbers per plant and average fresh tuber weight (Niragire et al., 2019).This agrees in the conclusion of an experiment to evaluate the influence of organic and inorganic fertilizer on the growth and yield of potato, where, (Baklawa et al., 2017) confirmed that the combination of inorganic fertilizer and organic manure showed significant effect particularly on the yield parameters of potato plants.

Figure 4.9

Effects of fertilizer treaments on the yields per hectare of potato.

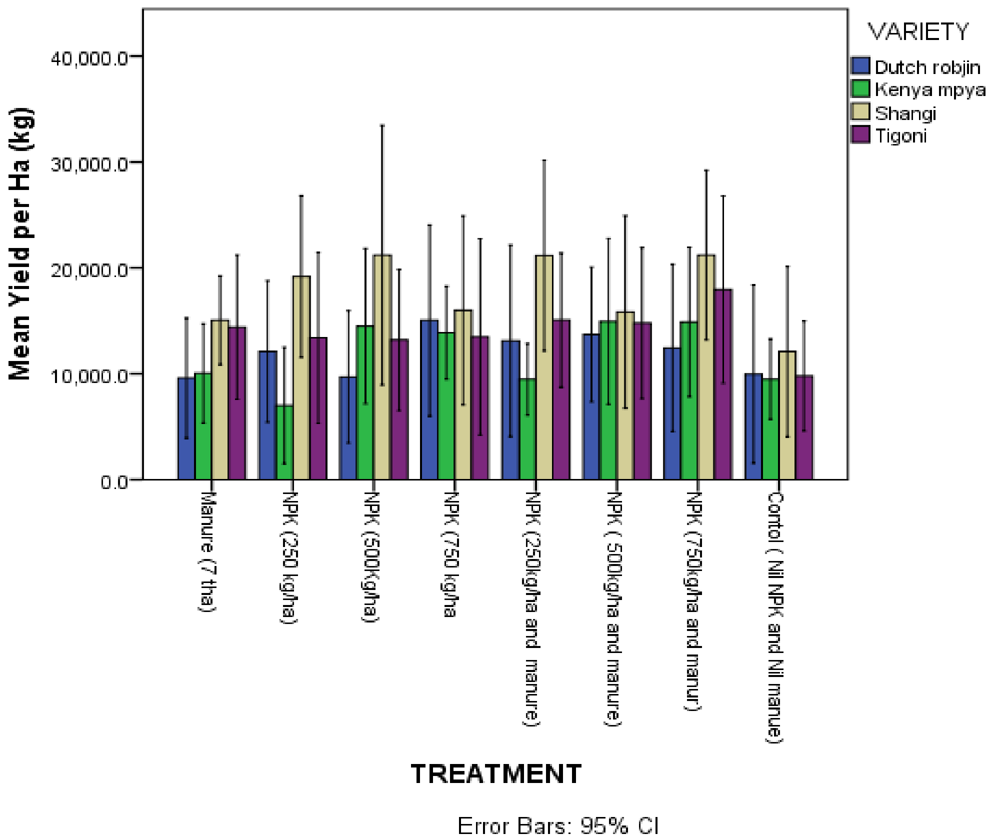


Table 4.14

ANOVA table on the effects of fertilizer treatments on the yields per hectare of potato.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	2474149751.494	1	2474149751.494	74.262	.000
Block	274882963.223	2	137441481.611	4.125	.018
VARIETY	1095573965.306	3	365191321.769	10.961	.000
Manure	105090809.569	1	105090809.569	3.154	.077
NPK	496940729.942	3	165646909.981	4.972	.002
Manure * NPK	27629259.221	3	9209753.074	.276	.842
VARIETY * Manure	44725289.946	3	14908429.982	.447	.719
Error	5830425323.408	175	33316716.134		
Total	10349418092.107	191			

a. R Squared = .437 (Adjusted R Squared = .385)

Table 4.15

LSD test for the effect of fertilizer treatments on the yield per hectare.

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		180.833	-5755.240*	-2047.788
Kenya mpya			-5936.073*	-2228.621
Shangi				3707.452
Tigoni				

*. The mean is significantly different at the 0.05 level...

Table 4.16

LSD test on the effects of different rates of fertilizer treatments on the yield.

	No NPK	250 kg/ha	500 kg/ha	750 kg/ha
No NPK		-2507.171*	-3428.969*	4303.971*
250 kg/ha			-921.798	-1796.800
500 kg/ha				-875.002
750 kg/ha				

*. The mean is significantly different at the 0.05 level.

4.11 Number of Tubers Per Plant

4.11.1 Charts (<56mm diameter)

There was some marked variation in the number of charts in all the varieties as shown in figure 4.10 (a) . Dutch Robjin indicated the highest number of charts compared to Shangi, Tigoni and Kenya Mpya. The ANOVA indicated significant difference between seasons,blocks and among the varieties with $p < 0.05$ as shown in the summary in table 4.17. The summary of the LSD conducted to separate the means of the varieties in table 4.18 confirmed that Dutch Robjin had significant difference in the number of charts as compared to Kenya Mpya. Shangi also indicated significant difference on the charts numbers compared to Kenya Mpya.

Figure 4.10 (a)

The Effects of fertilizer treatment on the charts.

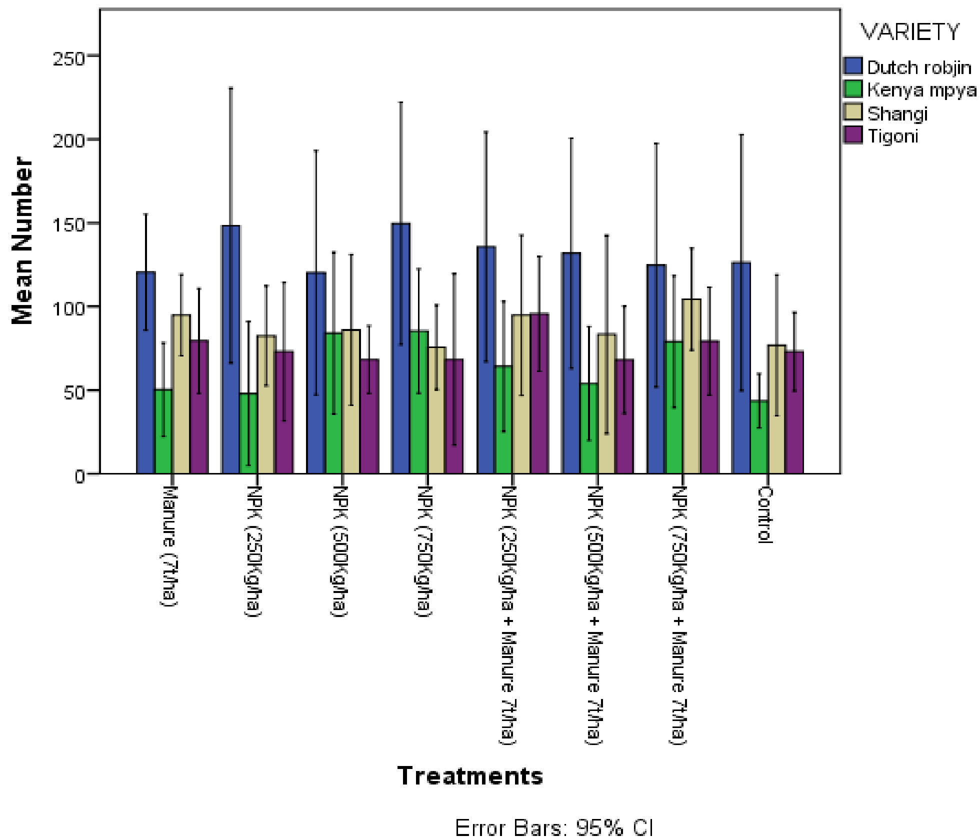


Table 4.17

The ANOVA effects on the number of charts.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	15016.688	1	15016.688	8.581	.004
VARIETY	128865.167	3	42955.056	24.545	.000
BLOCK	19931.698	2	9965.849	5.695	.004
Treatments	6664.583	7	952.083	.544	.800
Error	311508.531	178	1750.048		
Corrected Total	481986.667	191			

a. R Squared = .354 (Adjusted R Squared = .306)

Table 4.18

LSD test on the effects of fertilizer treatment on the charts.

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		68.54*	44.83	56.46*
Kenya mpya			-68.54*	-23.71*
Shangi				11.63
Tigoni				

Based on observed means. The error term is Mean Square(Error) = 1750.048.
*. The mean is significantly different at the 0.05 level.

4.11.2 Small tubers (56 – 63 mm)

The number of small tubers harvested was counted and presented in Figure 4.10(b) .The number of number of small tubers varied in the different seasons and varieties with Shangi producing the higher number of tubers compared to Dutch Robjin, Tigoni and Kenya Mpya. ANOVA indicated significant difference in the effect of treatment on season ($p \leq 0.000$) and variety ($p \leq 0.000$) Table 4.19 .The LSD on the effect of the variety indicated that Shangi is significantly different to Kenya Mpya (21) and Tigoni(9), while Tigoni is significantly different to Kenya Mpya(12) and Dutch Robjin is significantly different to Kenya Mpya(14) tubers as shown in Table 4.20.

Figure 4.10 (b)

The effects of fertilizer on small size tubers.

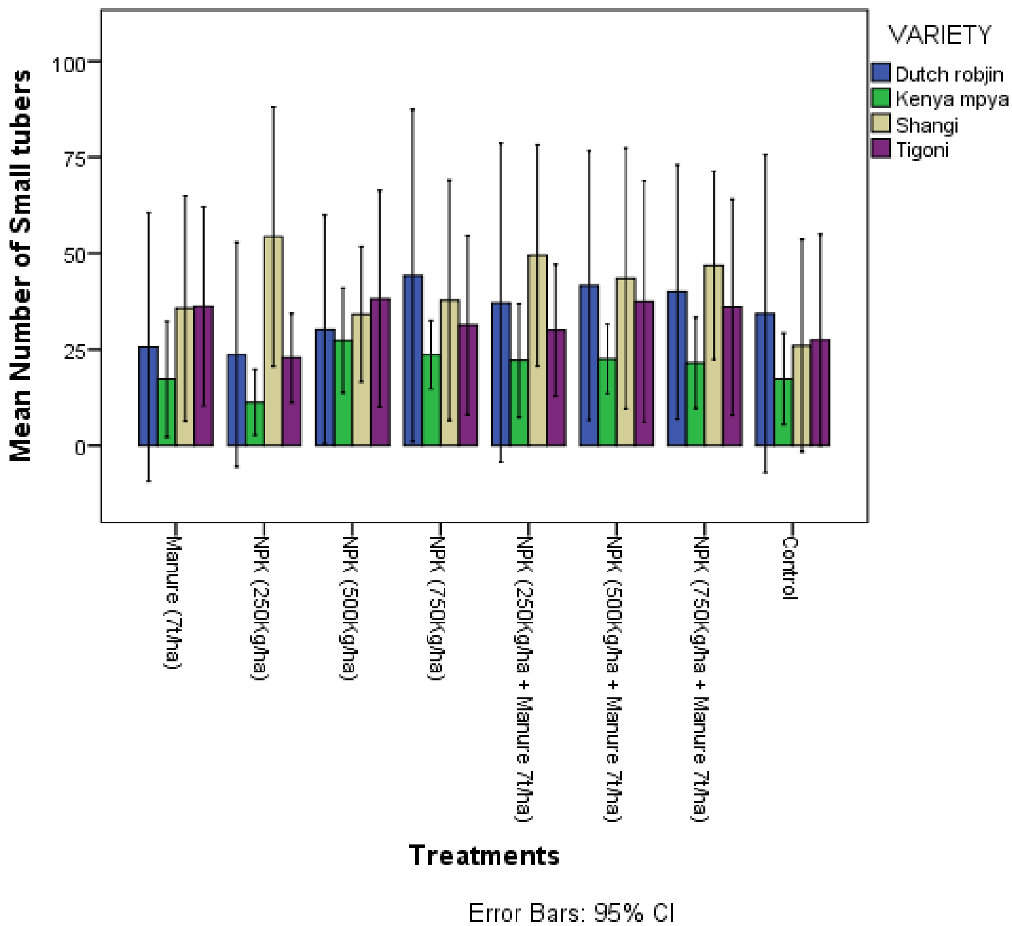


Table 4.19

ANOVA on the effects of fertilizer on small tubers per plot.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	40833.333	1	40833.333	111.086	.000
VARIETY	10666.167	3	3555.389	9.672	.000
BLOCK	5281.542	2	2640.771	7.184	.001
Treatments	2560.833	7	365.833	.995	.436
Error	65430.042	178	367.585		
Corrected Total	124771.917	191			

a. R Squared = .476 (Adjusted R Squared = .437)

Table 4.20

LSD test on the effects of fertilizer treatment on small tubers.

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		14.21*	-6.37	2.17
Kenya mpya			-20.58*	-12.04*
Shangi				8.54*
Tigoni				

The observed means.
The term error is the Mean Square(Error) = 367.585.
*. The mean is significantly different at the 0.05 level.

4.11.3 Medium tubers (64 – 75 mm).

The number of medium tubers were counted and presented in Figure 4.10 (c) . Shangi, generally had more medium size tubers compared to the other selected varieties with the application of NPK in all the treatments. There is significant difference in the number of medium potato tubers among the varieties($P \leq 0.000$) and treatments ($p \leq 0.008$)as shown in the ANOVA summary where the p values are lower than 0.05% as shown in Table 4.21. The LSD test indicated that Kenya Mpya had 6.04 more medium tubers compared to Dutch Robjin while Shangi was 11.21 better than Dutch Robjin and 5.17 better than Kenya Mpya. Tigoni also was 8.46 more than Dutch Robjin as shown in Table 4.22 . The least number of medium tubers were produced by Dutch Robjin . Applying 750kg/ha NPK plus cattle manure resulted in more medium tubers, this was comparable to when 500kg/ha NPK was applied. On the other hand, not applying nutrients to potatoes led to fewer medium tubers.

Figure 4.10(c)

The effects of fertilizer treatments on medium size tubers.

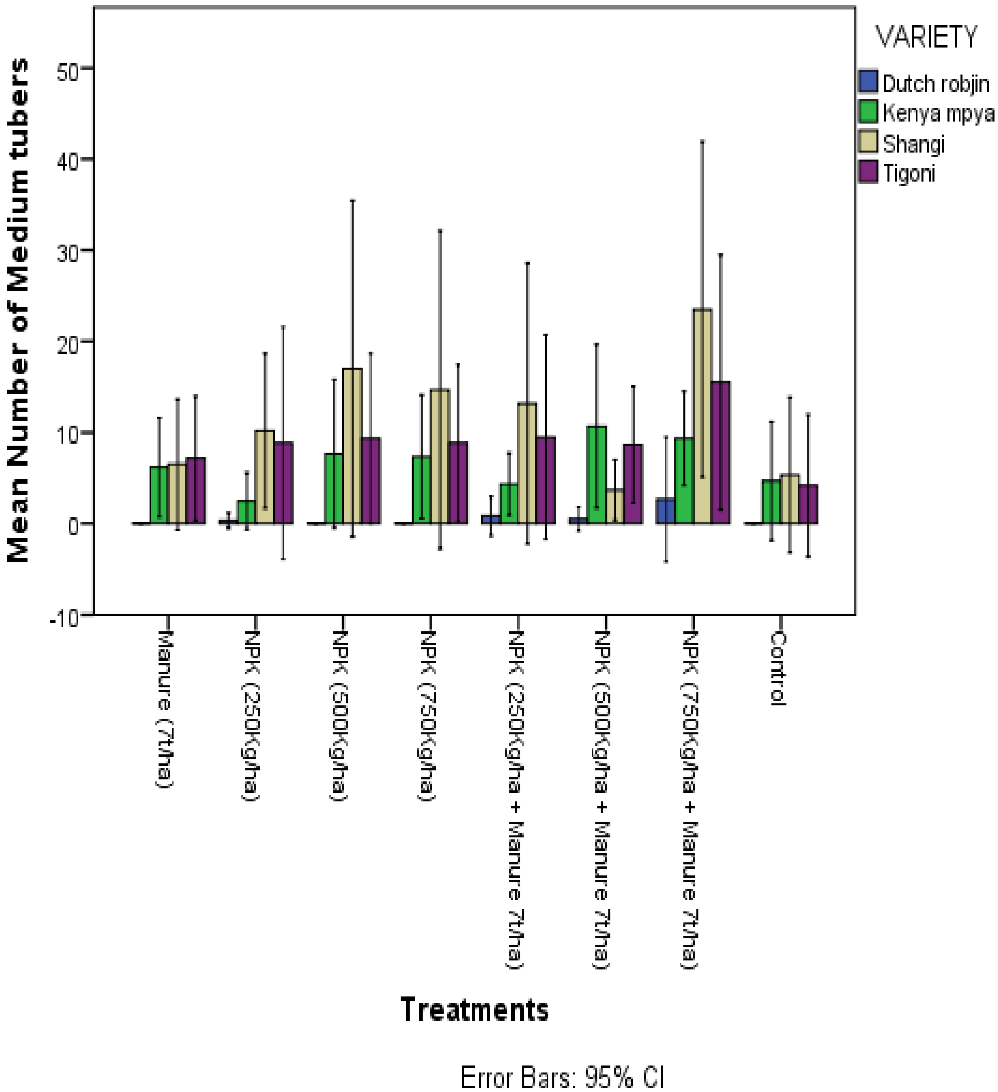


Table 4.21

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	963.021	1	963.021	14.403	.000
VARIETY	3285.229	3	1095.076	16.378	.000
BLOCK	200.344	2	100.172	1.498	.226
Treatments	1333.896	7	190.557	2.850	.008
Error	11901.323	178	66.861		
Corrected Total	17683.812	191			

a. R Squared = .327 (Adjusted R Squared = .278)

ANOVA table on the effect of fertilizer treatment on the medium size tubers.

Table 4.22

LSD test for the effect of fertilizer treatments on the number of medium size tubers per plot

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		-6.04*	-11.21*	-8.46*
Kenya mpya			-5.17*	-2.42
Shangi				2.75
Tigoni				

The observed means. The term error is the Mean Square(Error) = 66.861.
*. The mean is significantly different at the 0.05 level.

4.11.4 The number of large size tubers (76 – 84 mm)

The number of large potato tubers per variety and treatment are shown in Figure 4.10 (d). Kenya Mpya had more large size potato at fertilizer treatment of 500kg/ha and 750 kg/ha NPK with manure.Dutch Robjin did not produce any large size tubers in all the treatments. Shangi and Tigoni also had afew number of large size tubers in all the tratments.The ANOVA on the number of large tubers Table 4.23 showed that there were significant difference among varieties and seasons for large tubers. Kenya Mpya, Shangi and Tigoni had 1.69,1.35 and 1.33 more medium size tubers compared to Dutch Robjin as shown in Table 4.24.

Figure 4.10 (d)

The Effects of fertilizer treatments on the large size tubers

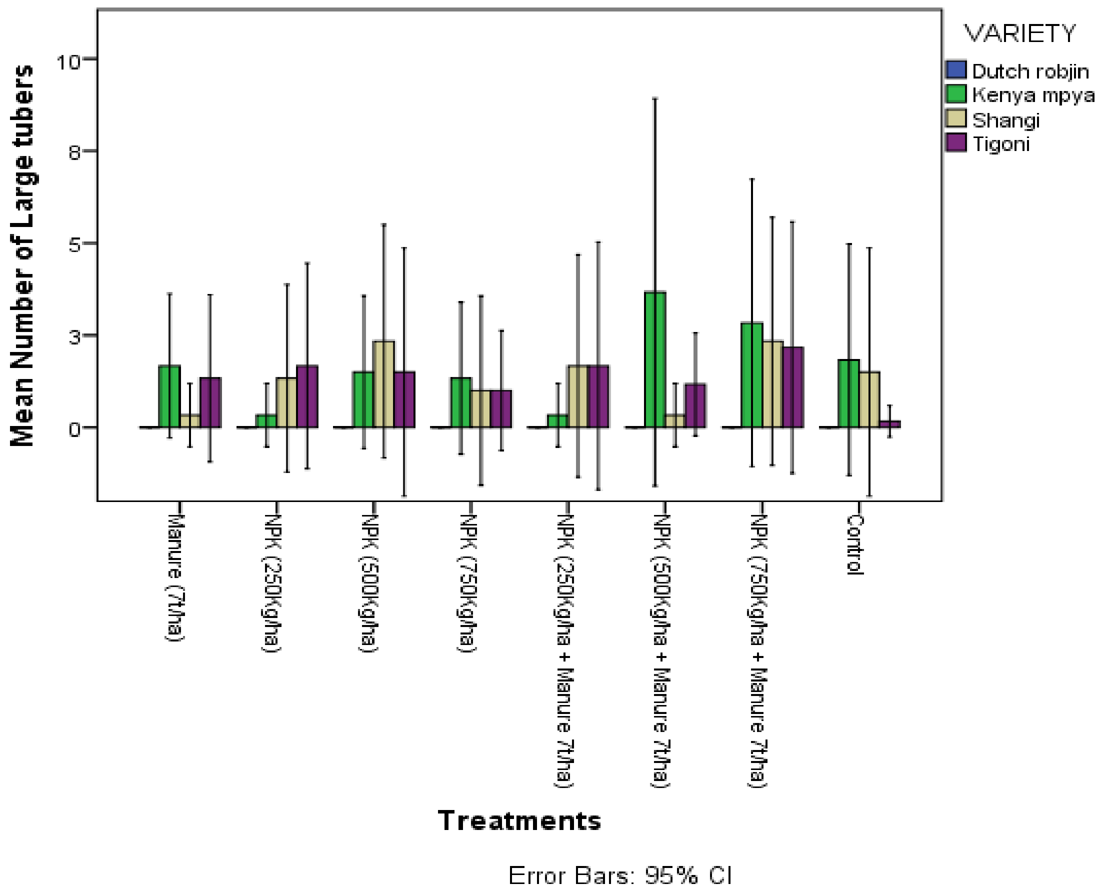


Table 4.23

ANOVA for on the effects on the number of large size of tubers.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	48.000	1	48.000	10.811	.001
VARIETY	80.354	3	26.785	6.033	.001
BLOCK	27.406	2	13.703	3.086	.048
Treatments	22.229	7	3.176	.715	.659
Error	790.323	178	4.440		
Corrected Total	968.313	191			

a. R Squared = .184 (Adjusted R Squared = .124)

Table 4.24

LSD test on the effects of fertilizer treatment on large size tubers.

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		-1.69*	-1.35*	-1.33*
Kenya mpya			.33	.35
Shangi				.02
Tigoni				

Based on observed means. The error term is Mean Square(Error) = 4.440.

*. The mean difference is significant at the 0.05 level.

4.11.5 The Number of extra large tubers (>84 mm)

The number of extra large tubers was counted and recorded and the data was summarized as shown in Figure 4.10 (e). Generally the number of extra large potato tubers was low compared to the other sizes. Shangi had 2 extra large tubere at 500 kg/ha NPK while the remaining treatments only yielding no extra large tubers.There was no significant difference among the four varieties on the number of extra large tubers as shown from the ANOVA in Table 4.25.

Figure 4.10(e)

The effects of fertilizer treatments on the extra large size tubers

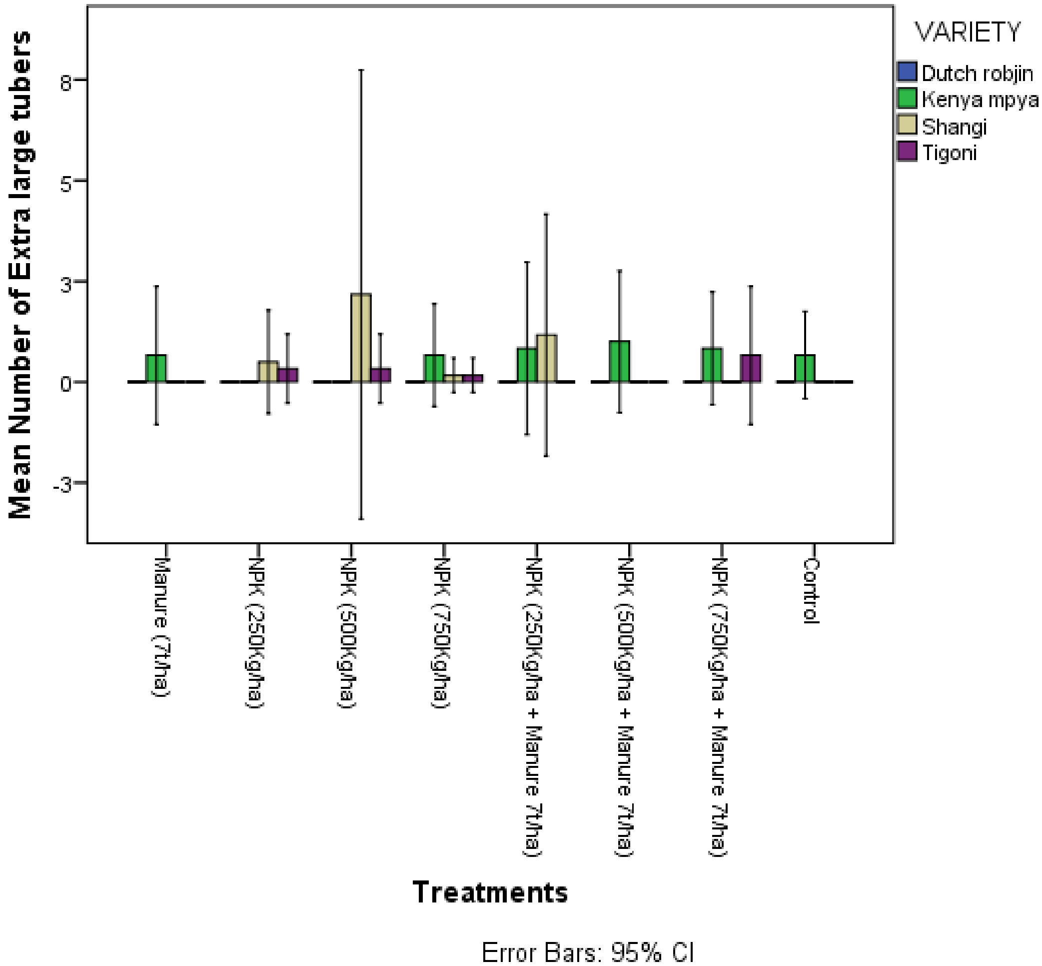


Table 4.25

ANOVA Table for the effects of fertilizer treatment on the number of extra large tubers.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	19.380	1	19.380	12.316	.001
VARIETY	10.641	3	3.547	2.254	.084
BLOCK	10.760	2	5.380	3.419	.035
Treatments	4.745	7	.678	.431	.882
Error	280.094	178	1.574		
Corrected Total	325.620	191			

a. R Squared = .140 (Adjusted R Squared = .077)

4.12 Dry Matter Content

Dry matter refers to the material that remains after the potato is dry. It plays an important role in determining its end use of the potato tuber with high dry matter content varieties used for processing and low dry matter content varieties are used for table purpose (Motawei, 2005). Potato is 75 to 85% water and the dry matter varies with variety, maturity, growing location, seasonal effects, fertilization program and the storage conditions (Bremner, 2009). The results of analysis of the dry matter content were summarized in Figure 4.11. There was no variation on the effects of the treatments.The

ANOVA however, indicated significant difference of the varieties at ($p \leq 0.003$) and the seasons ($p \leq 0.000$) as shown in Table 4.26. Shangi indicated higher dry matter compared to Dutch Robin and Kenya mpya at 1.23% and 2% respectively, while Tigoni had a higher dry matter content compared to Shangi by 2.06% as shown in Table 4.27. The study agrees with (Bekele, 2018) asertion that potato moisture content varies with variety, maturity, growing location and fertilizer.The results of Anjum and Sahair (2018) also agrees that dry matter content is determined by variety, fertilizer amounts and particular environmental conditions of a year. Hall (2019) also agrees that quality factors of potato considerably vary across seasons.

Figure 4.11

The effects of fertilizer treatment on the dry matter content.

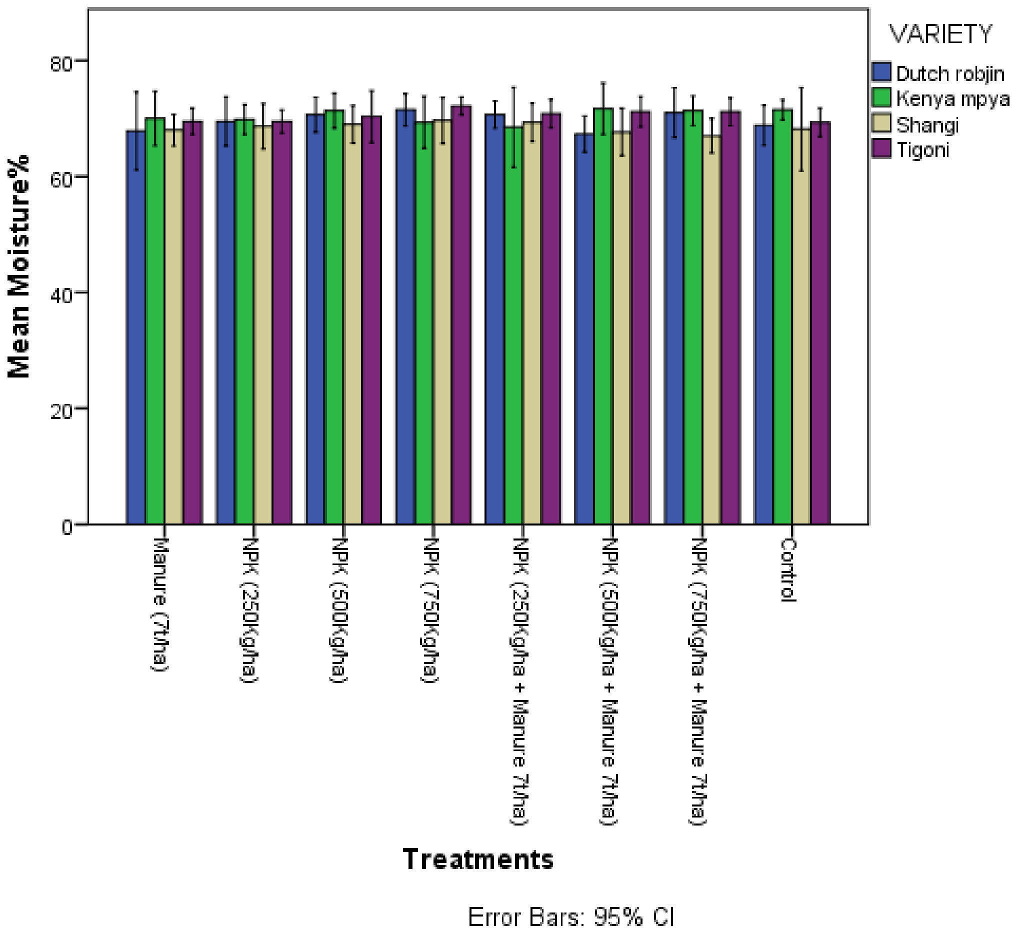


Table 4.26

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
SEASON	500.521	1	500.521	54.380	.000
VARIETY	132.688	3	44.229	4.805	.003
BLOCK	95.948	2	47.974	5.212	.006
Treatments	59.479	7	8.497	.923	.490
Error	1638.344	178	9.204		
Corrected Total	2426.979	191			

a. R Squared = .325 (Adjusted R Squared = .276)

The ANOVA table on the effects of fertilizer treatments on percentage (%) dry matter.

Table 4.27

	Dutch robjin	Kenya mpya	Shangi	Tigoni
Dutch robjin		.77	-1.23*	.83
Kenya mpya			-2.00*	.06
Shangi				-2.06*
Tigoni				

Based on observed means. The error term is Mean Square(Error) = 9.204.

*. The mean difference is significant at the 0.05 level.

LSD test on the effects of fertilizer treatments on the percentage (%) dry matter.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary, conclusion and the recommendations of the study.

5.1 Summary

This study addressed the fertilizer and cattle manure combinations required by the selected potato varieties for higher yields in the specific region of Taita hills in Taita Taveta County. Though, the results of this study are specific to a site and variety, they could be replicated in the other regions in Kenya adhering to the soil fertility status of those areas and the varieties.

5.2 Conclusion

The study resulted into various conclusions:

The potato variety that is more adapted to the agroecological conditions of the Taita hills is Shangi, it produced higher tuber yield, more medium, large and marketable tubers. Whereas Kenya Mpya produced the lowest tuber yield, Dutch Robjin produced fewer medium, large and marketable tubers. Summing the growth, yield and yield parameters, besides LAI and germination percentage, Dutch Robjin was less suitable for the Taita hills.

Potato grown in the first long rains season of march to june performed better than in the short rains season of october to december, thus first season in Taita hills is suitable for higher potato yields.

The application of 750 kg/ha NPK plus 7000 kg /ha of cattle manure led to higher yield, the yield was only considerably different from applying 7000 kg/ha cattle manure alone, 250 kg/ha NPK alone and no fertilizer application.

5.3 Recommendations

A cost benefit analysis on the production using the different fertilizer levels to be done for a more informed chouce on the appropriate practice to be adopted.This will be necessary to determine the most profitable fertilizer combinations that can be adopted by the farmers. More specifc studies to determine the site, variety and nutrient requirements in the area may be necessary so as to get a more acceptable trend.

5.4 Reommendations for Further Research

Similar studies need to be conducted, at different sites, within the agro ecological zones and during different seasons, in the Taita hills with the aim of collecting more data on the effect of the fertilizer levels.

REFERENCES

Akoto O., Acheampong, S. Okyem, C., & Baah, A. (2020). "Antioxidant, antimicrobial and FTIR analysis of methanol root extract of *Cnestis ferruginea* and ethanol root extract of Citrus limon," *Journal of Pharmacognosy and Phytochemistry,7*,2938–2946. https://doi.org/10.1155/2020/2153534

Anjum, J., & Sahair, S. (2018). Solanum tuberosum L: Botanical. *International Journal for phytomedicine*, *10*(3), 115-124. https://core.ac.uk/outputs/275977930

Baklawa, M., Niere, B., & Massoud, S. (2017). Influence of temperature and storage conditions on the hatching behavior of cereal cyst nematodes (Heterodera avenae Wollenweber) from Egypt. J. *Plant Dis.Prot*. 124, 213–225.https://doi.org/10.1007/s41348-016-0060-x

Balemi, T. (2009). Effect of phosphorus nutrition on growth of potato genotypes with contrasting phosphorus efficiency. *African Crop Science Journal*, 17(4), 199-212. https://www.ajol.info/index.php/acsj/article/view/54304

Bekele, G. (2018). Review on Nitrogen: Forms, Functions and Effects. *World Scientific News,101*(2018), 44- 54. http://www.worldscientificnews.com/wp-content/uploads/2018/04/WSN-101-2018-44-54-2.pdf

Bradshaw, J.E., & Ramsay, G. (2009) Potato Origin and Production. In: Advances in Potato Chemistry and Technology, *Academic Press, Burlington*, 1-26. https://doi.org/10.1016/B978-0-12-374349-7.00001-5

Bremner, J. (2009). *Determination of nitrogen in soil by the Kjeldahl method*. Cambridge University PressCIP (June, 5, 2022). *Farming Success with Potatoes in Kenya*. https://cipotato.org/media/farming-success-potatoes-kenya/2019 Cortada, L.

CKL Africa(2022) *Potato farming*. https://www.ckl.africa/potato-farming

Devaux A.,Kromann P., & Ortiz O. (2014). Potato for sustainable global food security. *Potato Research*, *57*(3-4), 185 – 199. https://doi.org/10.1007/s11540-014-9265-1

Drewnowski, A., & Rehm, C. (2013) Vegetable Cost Metrics Show That Potatoes and Beans Provide Most Nutrients Per Penny. PLoS ONE 8(5),e63277. https://doi.org/10.1371/journal.pone.0063277

Faggian, R., Powell, A., & Slater, A. T. (2012). Screening for resistance to potato cyst nematode in Australian potato cultivars and alternative solanaceous hosts.

Australas. Plant Pathol, *41*(2012), 453–461. https://link.springer.com/article/10.1007/s13313-011-0098-y

FAO (2017). *Combating Potato Cyst Nematode (PCN) in Kenya*. FAO publications, 1–2.

Goeminne, M., Demeulemeester, K., & Viaene, N. (2011). A method for estimating the contribution of seed potatoes, machinery and soil tare in field infestations with potato cyst nematodes on a national scale. *Commun. Agric. Appl. Biol. Sci, 76*(3), 311–318. https://pubmed.ncbi.nlm.nih.gov/22696943/

Gouy, M., Guindon, S., & Gascuel, O. (2010). SeaView version 4: a multiplatform graphical user interface for sequence alignment and phylogenetic tree building. *Mol. Biol, 27*(2), 221– 224. https://doi.org/10.1093/molbev/msp259

Hall, T. A. (2019). BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucl. Acids*. Symp. Ser. 41, 95–98. http://www.sciepub.com/reference/87002

Janssens, S. R. M., Wiersema, S. G., Goos, H., & Wiersma, W. (2013). *The Value Chain for Seed and Ware Potatoes in Kenya Opportunities for Development.* LEI Wageningen University & Reasearch https://edepot.wur.nl/279729

Kenya Plant Health Inspectorate Services (KEPHIS). (2016) *Seed Potato Production Certification Guidelines Handbook.* LEI Wageningen University & Reasearch

Khanal, S., & Subedi, S. (2019). Effects of potassium levels on growth and productivity of potato varieties in inner terai of Nepal. *Journal of Agriculture and Natural Resources, 2*(1), 274-281. https://doi.org/10.3126/janr.v2i1.26090

Lansink, A. O., Verstegen, J., & Hengel, V. D. (2018). Investment decision making in Dutch greenhouse horticulture. *Netherlands Journal of Agricultural Science, 49* (4), 357-368. https://library.wur.nl/ojs/index.php/njas/article/view/657

Lardy, N., Prakash, A. B., Lutaladio, N., & Ezeta, F. (2022). *Strengthening Potato Value Chains: Technical and Policy Options for Developing Countries*. Food and Agriculture Organization of the United Nations (FAO).

Lusine, A., Alfons, L. O., & Jos, V. (2007). Factors underlying the investment decision in energy- saving systemsin Dutch horticulture. *Elsevier*, 94, 525. DOI:10.1016/j.agsy.2007.01.005

Mburu, H., Cortada, L., Mwangi, G., Gitau, K., Kiriga, A., & Kinyua, Z., (2018). First report of potato cyst nematode *Globodera pallida* infecting potato (*Solanum* *tuberosum*) in Kenya. *Plant Dis*. 102(8), 1671–1671. https://www.cabi.org/ISC/abstract/20183271433

Motawei, A. (2005). Effect of various potassium and nitrogen rates and splitting methods on potato under sandy soil and arid environmental conditions. *Emir. J. Agric. Sci*. 2005, *17* (1), 01- 09. https://www.bibliomed.org/mnsfulltext/137/5043-13636-1-PB.pdf?1666519084

Muthoni, W. (2016). *Post-harvest Losses in Potato Value Chains in Kenya: Analysis and Recommendations for Reduction Strategies*. Internationale Zusammenarbeit (GIZ) GmbH.

Najim, M. R. (2010). Effect of Utilization of Organic and Inorganic Nitrogen Source on the Potato Shoots Dry Matter, Leaf Area Index and Plant Height, During Middle Stage of Growth. *International Journal of Agricultural and Biological Sciences*, *4*(11), 852-855. http://scholar.waset.org/1307-6892/15448

National Potato Council of Kenya (NPCK). (2017, November, 23).*Potato Variety Catalogue, 2017 Handbook.* https://npck.org/potato-magazines/npck/

National Enviromental Management Authority. (2009). *Environment Action Plan Taita Taveta* District 1999-2009. National Enviromental Management Authority

Niragire, I., Couvreur, M., Karssen, G., Uwumukiza, B., & Bert, W. (2019). First report of potato cyst nematode (Globodera rostochiensis) infecting potato (Solanum tuberosum L.) in Rwanda. *Plant Dis*, *104*(1), 104:293. https://doi.org/10.1094/PDIS-04-19-0891-PDN

Nwibo, S. U., & Alimba, J. O. (2013) Determinants of Investment Decisions Among Agribusiness Investors in South-East, Nigeria. *IOSR Journal of Business and Management* 8(6), 60–67. https://www.academia.edu/RegisterToDownload

Okello, J. J., Kirui, O., Njiraini, G. W., & Gitonga, Z. (2012). Drivers of Use of Information and Communication Technologies by Farm Households: *The Case of Smallholder Farmers in Kenya*. Agricultural Science, 4(2), 111-124. https://doi.org/10.5539/jas.v4n2p111

Okello, J. J., Zhou, Y., Kwikiriza, N., Ogutu, S., Barker, I., & Shulte-Geldermann, E. (2017). Productivity and food security effects of using of certified seed potato: the case of Kenya's potato farmers. *Agric. Food Secur*, *6*(25), 25–34. https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/s40066-017-0101-0

Okello, Y. Z. G. (2017). *Productivity and food security effects.* Agriculture & Food Security.

Park, J., Yang, H., De Jong, W. S., & Wang, X. (2018). An evaluation of two H1-linked markers and their suitability for selecting *Globodera rostochiensis* resistant potatoes in the New York breeding program. Am. J. Potato Res. 95, 170–177. https://link.springer.com/article/10.1007/s12230-017-9623-z

Perry, R. N. (2002). "*Hatching," in Biology of Nematodes*. Taylor and Francis.

Prokop, S., & Albert, J. (2008). *International Year of the Potato*. Retrieved December 12, 2019, from Food and agriculture Organization: http://www.fao.org/potato2008/en/potato/factsheets.html.

Rodriguez, V. (2011). *Factors underlying the investment decision in energy-saving systemsin Dutch horticulture*.Elsevier.

APPENDICES

1. Laboratory Results on Soil Analysis.

UNIVERSITY OF NAIROBI

COLLEGE OF AGRICULTURE AND VETERINARY SCIENCES

FACULTY OF AGRICULTURE

Department of Land Resource Management and Agricultural Technology (LARMAT)

P.O BOX 29053 - 00625, KANGEMI, NAIROBI

TEL: 631225 (DL) 3592736 – 9 Ext. 27021 **FAX**: 631225

Email Address: larmat@uonbi.ac.ke

SOIL ANALYTICAL DATA- TTU-NGERENYI CAMPUS

							Cmol/kg				**Ppm**		
Lab No	**Sample ref**	**PH(H_2O)**	**%O.C**	**%N**	**K**	**Na**	**Ca**	**Mg**	**Zn**	**Cu**	**Fe**	**Mn**	**p**
461/21	T. soil	6.02	3.95	0.40	0.62	0.65	3.16	0.79	7.40	1.85	28.5	16.4	96.2
462/21	T. compost	8.78	7.90	1.05	3.05	1.10	16.8	8.5	10.1	0.64	40.5	53.8	1050

2. Laboratory Results on Dry matter Analysis (Season 1&2).

Season1

Sample ID		Fresh weight(g)	Dry weight(g)	DM %	Moisture%
Rep 1	1	74.7459	22.2387	29.752401	70.247599
Rep 1	2	60.9055	19.5061	32.026828	67.973172
Rep 1	3	47.9632	17.4266	36.333272	63.666728
Rep 1	4	63.5552	19.4532	30.608353	69.391647
Rep1	5	81.2689	28.9912	35.673179	64.326821
Rep1	6	67.0747	23.2713	34.694602	65.305398
Rep1	7	63.4293	21.4942	33.886863	66.113137
Rep1	8	60.3038	16.1743	26.821361	73.178639
Rep1	9	67.427	19.5115	28.937221	71.062779
Rep1	10	67.5936	23.7271	35.102584	64.897416
Rep1	11	69.9758	21.6389	30.923405	69.076595
Rep1	12	62.6199	18.9468	30.256835	69.743165
Rep1	13	56.8887	17.1246	30.101936	69.898064
Rep1	14	75.8112	21.1158	27.85314	72.14686
Rep1	15	72.995	21.807	29.874649	70.125351
Rep1	16	57.0041	19.0232	33.371635	66.628365
Rep1	17	79.0002	25.4501	32.215235	67.784765
Rep1	18	74.0667	24.4651	33.031173	66.968827
Rep1	19	58.3235	19.7819	33.917546	66.082454
Rep1	20	70.097	23.7755	33.917999	66.082001
Rep1	21	66.5281	20.6667	31.064618	68.935382
Rep1	22	70.4418	19.9541	28.327073	71.672927

Rep1	23	67.5742	21.3953	31.661936	68.338064
Rep1	24	65.0435	18.6928	28.738921	71.261079
Rep1	25	71.208	25.588	35.934165	64.065835
Rep1	26	91.746	27.4463	29.915528	70.084472
Rep1	27	54.5034	19.81	36.346356	63.653644
Rep1	28	76.4116	24.745	32.383827	67.616173
Rep1	29	52.3354	16.7384	31.982941	68.017059
Rep1	30	70.4276	21.4175	30.410663	69.589337
Rep1	31	90.4447	25.5377	28.235706	71.764294
Rep1	32	59.0089	21.105	35.765791	64.234209
Rep2	1	75.2528	21.6691	28.795075	71.204925
Rep2	2	75.5276	25.4008	33.631149	66.368851
Rep2	3	85.4545	28.4604	33.304741	66.695259
Rep2	4	89.574	28.9558	32.326121	67.673879
Rep2	5	62.8764	19.7089	31.345465	68.654535
Rep2	6	85.9095	20.8518	24.271821	75.728179
Rep2	7	84.3714	26.036	30.858798	69.141202
Rep2	8	86.6436	23.7599	27.422568	72.577432
Rep2	9	71.6902	20.5741	28.698623	71.301377
Rep2	10	71.4382	24.7813	34.689144	65.310856
Rep2	11	89.0064	23.9178	26.872	73.128
Rep2	12	78.7692	22.8737	29.038888	70.961112
Rep2	13	80.8632	19.1288	23.655754	76.344246
Rep2	14	85.0563	27.1608	31.932732	68.067268
Rep2	15	78.5814	21.757	27.687214	72.312786
Rep2	16	77.9279	24.437	31.358474	68.641526
Rep2	17	106.0248	27.7662	26.188401	73.811599
Rep2	18	62.9018	17.2088	27.3582	72.6418

Rep2	19	84.1897	25.0215	29.720381	70.279619
Rep2	20	75.4485	20.6371	27.352565	72.647435
Rep2	21	116.8986	25.0002	21.386227	78.613773
Rep2	22	70.4636	23.6723	33.595076	66.404924
Rep2	23	91.4968	24.9062	27.220843	72.779157
Rep2	24	83.4034	26.9382	32.298683	67.701317
Rep2	25	92.2961	27.3004	29.579148	70.420852
Rep2	26	79.7841	21.9518	27.514003	72.485997
Rep2	27	75.1109	21.2019	28.227461	71.772539
Rep2	28	79.0268	26.6084	33.670097	66.329903
Rep2	29	80.8935	23.489	29.036944	70.963056
Rep2	30	81.391	29.6498	36.428843	63.571157
Rep2	31	74.1319	24.056	32.450268	67.549732
Rep2	32	96.1673	27.0831	28.162484	71.837516
Rep3	1	86.7932	23.497	27.072397	72.927603
Rep3	2	78.4227	21.7951	27.791826	72.208174
Rep3	3	104.0419	29.535	28.387602	71.612398
Rep3	4	89.3272	27.3611	30.6302	69.3698
Rep3	5	80.8013	26.6517	32.984247	67.015753
Rep3	6	73.1836	21.0236	28.727201	71.272799
Rep3	7	87.6323	28.631	32.671743	67.328257
Rep3	8	95.6932	27.2884	28.516551	71.483449
Rep3	9	76.4816	22.412	29.30378	70.69622
Rep3	10	84.3442	27.2998	32.367134	67.632866
Rep3	11	83.5461	23.1273	27.682082	72.317918
Rep3	12	92.4471	32.6071	35.27109	64.72891
Rep3	13	89.111	29.9492	33.60887	66.39113
Rep3	14	83.1167	23.9991	28.873981	71.126019

Rep3	15	94.0067	27.2359	28.972297	71.027703
Rep3	16	93.0067	26.6309	28.633314	71.366686
Rep3	17	103.1752	26.3646	25.553234	74.446766
Rep3	18	95.7886	32.043	33.451789	66.548211
Rep3	19	89.9221	26.0867	29.010332	70.989668
Rep3	20	113.4767	29.8282	26.285749	73.714251
Rep3	21	89.9109	29.4015	32.700707	67.299293
Rep3	22	87.2723	24.8105	28.428837	71.571163
Rep3	23	62.6739	19.7222	31.467964	68.532036
Rep3	24	85.8438	29.6203	34.50488	65.49512
Rep3	25	85.6915	25.0601	29.244558	70.755442
Rep3	26	78.0998	25.1162	32.159109	67.840891
Rep3	27	87.5172	28.518	32.585595	67.414405
Rep3	28	73.6959	21.6432	29.368255	70.631745
Rep3	29	87.3111	29.5905	33.89088	66.10912
Rep3	30	72.5459	21.3848	29.477613	70.522387
Rep3	31	79.8322	23.4753	29.405804	70.594196
Rep3	32	75.6187	22.9702	30.376349	69.623651