EFFECTS OF FERTILIZATION AND SPACING ON GROWTH AND GRAIN YIELDS OF FINGER MILLET (*Eleusine Coracana* L.) IN AINAMOI, KERICHO COUNTY

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DECLARATION AND RECOMMENDATION

This thesis is my original work and has not been submitted for any degree or any other award in any other university.

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DEDICATION

I dedicate this thesis to my wife and children for their endless support and my friends for inspiring me through the study period.

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ABSTRACT

Finger millet was once an important diet in Southern Africa since it was annual cultivation of cereal commonly cultivated in multiple ecological areas in Kenya for its seed. The cereal crop, an extremely nutritious meal for baby food, special dishes for ill individuals and unique drinks, is used for some individuals such as "eraki" beer. In Ainamoi, Kericho County, a field trial has been performed to assess the effects of separation and fertilizer concentrations on Finger Millet development and outputs (*Eleusine coracana*). There were three types of plant spacing and fertilizer. The RCBD experiment was laid out with three replicates. The results showed that the effect of spacing on plant height was not significant (P=0.918). Fertilizer effect was significant (P=0.00), while the interaction effect of spacing and fertilizer (P=0.999). The spacing had no significant difference in leaf length (P= 0.556). Whereas the fertilizer effect had a significant effect on leaf length (P= 0.00). The interaction effect of spacing and fertilizer was not significant (P=0.998). Furthermore, the results indicated that fertilizer application showed a significant difference in the number of tillers (P= 0.003), while spacing had no significant difference (P= 0.316). The interaction effect of fertilizer and spacing had no significant difference with the number of tillers formed. Results showed that spacing had no significant difference in the number of heads formed (P= 0.624), but fertilizer effect showed a significant difference (P=0.004). Also, the interaction effect of fertilizer and spacing was not significant (P=0.930). With regards to biomass, results showed that fertilizer had no significant difference in biomass, (P=0.009), while spacing had a significant difference (P=0.005). The interaction effect of fertilizer and spacing had no significant difference in biomass (P=0.777). Finally, it was observed that fertilizer application and spacing had a significant difference in the grain yield, with a P-value of 0.004, and 0.002 respectively. Furthermore, the interaction effect of fertilizer and spacing did not show any significant difference (P=0.764). It is recommended that farmers adopt the closer spacing of 20x10 cm for Finger millet in the study area for higher crop yield and farmers to apply a minimum of 125 kg DAP/ha. However, specific soil tests are recommended to establish the appropriate levels at which to apply the N and P fertilizers. Further research is recommended to establish the correct plant populations for optimum production as the current three levels were inadequate for a conclusive determination of the exact plant population desirable for the variety P224.

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
BNF	Biological Nitrogen Fixation
CAN	Calcium ammonium nitrate
DAG	Days after germination
DAP	Di-ammonium phosphate
ha	Hectares
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ISFM	Integrated Soil Fertility Management
ITK	Indigenous Technical Knowledge
KARLO	Kenya Agricultural & Livestock Research Organization
KARI	Kenya Agricultural Research Institute
LSD	Least Significant Difference
MLND	Maize Lethal Necrosis Disease
PPM	Parts per million
TOC	Total organic Carbon
SPSS	Statistical Package for Social Sciences
SSA	Sub Saharan Africa
SSP	Single superphosphate
TRI	Tea Research Institute
TSP	Triple superphosphate

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Millet is a group of small seeds cultivated primarily for livelihood and forage throughout the globe. Millet is known for its adaptation to the hostile setting of arid and semiarid are as, as it is a hunger-mitigating plant. Finger millet (*Eleusine coracana (L.) Gaertn*.) is one of the vital crops grown for grain and fodder purpose under varied agro-climatic conditions (Hrideek & Nampoothiri, 2017).

1.1 Background Information

The impacts of climate change have greatly threatened agriculture in eastern Kenya. This is due to the arid and semi-arid climate, with low erratic precipitation and elevated temperatures in the region. In eastern Kenya, food scarcity has always been a big issue as low fertility and low precipitation is intrinsic to it. With growing climate impacts and variability, there is an expectation that extended drought will boost food insecurity, without a doubt (Chandra, Chandra & Sharma, 2016).

Farmers in eastern Kenya are able to deal with climate change by cultivating indigenous plants like finger millet. For socio-economic and cultural factors, these plants that are likely to contribute to food security, health, foodstuffs, revenue and environmental services have been abandoned. Finger millet has numerous attractive characteristics which promote its use as a crop to combat climate change. Finger millet can generate excellent returns with low inputs (Taylor, 2016).

The cereal production in semiarid areas of the globe is ranked fifth in the semitone manufacturing of cereals after that, according to Fetene, Okori, Gudu, Mneney and Tesfaye (2011), the cereal sector is mainly eaten by marginalized populations of semiarid Africa and Asia as a subsistence source for agricultural workers including sorghum (*Sorghum bicolour*) and pearl millet (*Pennisetum glaucum*).

It is highly valued by local farmers for its ability to grow in adverse agro-climatic conditions, where cereal crops such as maize (*Zea mays*), wheat (*Triticum spp.)* and rice (*Oryzasativa*) fail and has been noted to tolerate a wide variety of soils. Annual rainfall of 500 to 1000 mm is required in order to be ecologically well distributed during the growing season, and it is adapted to a broad variety of soil circumstances, although fertile, well-drained sandy to loamy soils of pH range from 5 to 7. In lateritic or black heavy vertisols, finger millet also develops tolerant of alkaline and mildly salty soils. In terms of altitude, in eastern and southern Africa the crop is between 1000 to 2000 meters higher and in Quattrocch (2006), between 2, 500 and 3, 000 meters above sea level in the Himalayas.

Millet is a variety of small-grained cereal grown around the world for sustenance and fodder purposes. Millet is said to be a crop of hunger mitigation as it is well adapted and cultivated under the harsh environment of arid and semi-arid regions. Finger millet (*Eleusine coracana* (L.) *Gaertn*.) is one of the important crops grown under varied agro-climatic conditions. Finger millet belongs to the *Poaceae* family and is one of the most important food cereals in Sub-Saharan Africa. According to Chandra, Chandra and Sharma (2016), finger millet being a cereal, it is one of the staple food crops for a large number of people in semi-arid areas and other regions of the world, particularly in Africa and India, and especially those who live by subsistence farming. Ethiopia is regarded as the Centre of finger millet diversity.

As its originates from Eastern Africa, finger millet is widely grown by small scale landholders for food and as a source of income where at present it fetches a better price than maize and sorghum per kilogram (Taylor, 2016). “Wimbi” is the name for the millet in Kenya and is mostly grown in the Western and parts of the Rift Valley as well as of Eastern region. This crop is so nutritious and among the best of the most major cereals. It is rich in minerals especially in phosphorus, calcium and iron; it has high in carbohydrates that are important especially for infants, mothers, elderly and the sick (Thilakarathna & Raizada, 2015). Its protein contains salient amino acids like methionine and valine; high dietary fibre; and for all its importance, however, this crop is one of the most neglected and underutilized crops worldwide again, the researchers have put minimal attention on the same as compared to that carried out in wheat, rice, and maize, for instance.

Due to the constraints such as limited research, soil fertility, soil nutrients depletion, and inefficiency in fertilizer use, its production has alarmingly dwindled through the years. Studies done on soils in Western Kenya have depicted low soil N and P contents emphasizing the need for the application of inorganic fertilizers that are vital to overcome the decline or alleviate the soil nutrient deficiency (Belay & Gebreslasie, 2016).

Finger millet is grown at 2,400 m above the sea leave and grows in a wide range of types and tolerant notably high rainfall and a certain alkalinity levels. It is appreciated as a low soil fertility crop that is grown as far west as in Central Nigeria. Finger millet is wide-spreading in warm temperature regions form Australia, Japan to Africa also grows in Northern Ireland colder regions during the summer season. The agronomy of finger millet is vital in improving and sustaining the crop quality, production and productivity. Application rates for soil nutrients, nitrogen fertilizer application schedule, seed rate and spacing (planting method) have become the most vital agronomic practices. According to Sidibé, Sanou, Bayala and Teklehaimanot (2017), the competition for plant nutrients and sunlight becomes high with the increase of plant density. This will lead plant growth to slow down and the grain yield decreasing. The reverse situation is the same since a situation of low millet plant density will result in below expectations yield plateau. Ascertainment of the most advantageous of plant population per unit area is, therefore, appropriate under spacing to obtain maximum crop yields. Addressing plant density with respect to soil fertility and finger millet variety is very important (Debenport et al., 2015).

The availability of finger millets and in adverse agro-climate conditions, local farmers highly value the product, where cereal crops such as wheat (*Triticumspp)* rice (*Oryzasativa)* and maize (*Zea mays*) fail and has been noted to condone a wide variety of soils. Ecological requirements for the crop shows that it requires 500-1000 mm annual rainfall of which it is well distributed throughout the growing season; the crop is also well used to a wide range of soil types and order provided the soils are fertile with a pH of between 5, owing to its preference for such. Additionally, the crop (Finger millet) prefers lateritic or black heavy vertisols while it is tolerant to moderately saline and for alkaline soils (Debenport et al., 2015).

Phosphorus (P) is deficient in most of the soils throughout the world; soils in Kericho are usually acidic in reaction and lateritic in nature. Available micronutrients and macronutrients traces are usually contained in these types of soils. Insufficient of some macronutrients have occurred in the country with the introduction of high yielding crop varieties, increased cropping intensity coupled with a heavy application of N and P fertilizers. Different crop yield has been noticed from the beneficial effect on soil application of the deficient macronutrients and one of the major causes depressing the productivity of the crops is the poor performance of phosphorous fertilizers (Thilakarathna & Raizada, 2015). Hence, the effect of phosphorus on root development is not well established. Additionally, nitrogen and phosphorus fertilizer enhance root development which leads to improvement in the supply of other water and nutrients to the developing parts of the plants which result in the increase in photosynthetic area and thereby more grain yields and dry matter accumulation (Hasan, 2016).

Potassium is vital for photosynthesis and helps in osmotic pressure balance hence plant turgidity and for fruit (head) formation. Chemical fertilizers or organic manures are used to provide these nutrients. Despite the crop being very important finger millet, research attention given to the crop has been low and the information is scarce on the P management of the crop is limited. Good crop husbandry practices applied to existing varieties can lead to achieving potential crop yields. Establishing the optimum amount of the P fertilizer for application for maximization of the crop yields while ensuring the environmental compromising effects are avoided is therefore very necessary (Nelson-Wekha et al., 2016).

Inorganic fertilizers are readily available with suppliers but more information on the application of different and correct levels in the crop production will help to optimize on both production and yields. In the region of Kericho East sub-County, fertilization has in the past formed a component of improved cultural practices for most crops with the land under frequent cultivation forming 90 per cent of the total arable. Yields below potential levels have been caused by constraints and problems of soil nutrients of low to medium availability levels. Among the high-level nutrients that limit finger millet yield is N, due to the fact that a number of the soils under the cultivation of finger millet have Soil N levels ranging from medium to low, that is 75 to 330 kg N/ha. However, since it is a highly mobile nutrient, N levels are degraded easily due to cultivation or crop systems (Sileshi et al., 2019).

To prevent soil infertility or degradation, the best way is to put back what the crop has taken from up from the soil by application of nutrients and this can only be reversed through the application of inorganic fertilizer coupled with manures and other organic fertilizers. A study carried out by Hemalatha and Chellamuthu (2013) established that fertilization of the soil by adding of inorganic N fertilizer has the effect of reducing organic carbon level of the soil as a result of the low send back of crop residues to the field and low dry matter production. It was found that the proper schedule of N application is vital in finger millet production, while the amount of N supplied is equally critical. N application initiates with seed germination and it is very important, which is a very big challenge for finger millet and other small crops more so in nutrient-deficient conditions. Inorganic fertilizer N application at planting stage stimulates good crop emergence when soil is deficient in Nitrogen (Agegnehu, Nelson & Bird, 2016).

1.2 Statement of the Problem

Several factors to be determined for every successful cultivation of a crop. Most Kenyan farmers use mineral-based fertilizer solutions forgoing the consideration of the optimum level that is necessary for minimizing crop production loss, yield maximization, reduction of wastage and reduction in the use of inorganic fertilizer. Fertilization is a very important aspect of the production system of different crops. Optimum sowing and plant spacing ensure proper growth and enlargement of plant resultant to maximum yield of the crop and economic use of land. The finger millet yield has been revealed to depend on the number of crops per unit of soil. The crop population and organisation, where finger millet is not outstanding, may obviously affect crop growth, growth and marketable output of many grain plants. The connection between plant growth and population can be complicated because development depends on the genotype of the plants. The close proximity within the roots and shot the microenvironments affect the interaction of the adjacent crops. When competitive or allopathic, such interactions might affect plant growth and development. Under inadequate circumstances of soil water, favourable plant population of a crop should be smaller. The contrary is also true; under-watered circumstances, the population of plants may be greater.

It is for this reason that this study was conducted to find the best spacing of finger millet in Ainamoi, Kericho County. It’s also worth noting that most farmers in the area of study use mineral-based fertilizer solutions forgoing the consideration of the optimum level that necessary for minimizing crop production loss, yield maximization, reduction of wastage and soil-toxicity reduction. For that reason, this study mainly established the optimum level or amount of chemical fertilizer Di-Ammonium Phosphate (DAP) required for maximum growth, production, and yield levels of finger millet under the prevailing quality of the soil and climatic of the same area.

1.3 Justification of the Study

Therefore plant population and spacing can have a significant effect on plant growth, marketability and finger millet yield. Finger millet is primarily cultivated in semi-arid tropics where significant and micronutrient deficiencies occur. This is because of the low use of mineral fertilizer and mainly the continuous production, poor crop rotation and reduced application of organic matter can effectively reduce the potential as reported

(Anantha et al.,2016). Optimizing nutrient management practices is seen as important to improving returns when farming under relative marginal local circumstances, among other associated factors. Regrettably, unlike other grains, empirical research and nutrient management recommendations are restricted and scarce, thereby impeding the capacity of farm extension officers to assist subsistence farmers. Inadequate data on the right concentrations of fertilizer application and the cost efficiency of agricultural inputs resulted in a low crop output and elevated market demand for the crop.

1.4 General Objective of the Study

The study objective aims at evaluating the growth of finger millet (variety P224) at different amounts/levels of fertilizer application and spatial arrangements in Ainamoi, Kericho County.

1.5 Specific Objectives

To achieve the above main objective, the study was led by the following specific objectives:-

i. The effect level growth and yield of finger millet (P224 variety).was to be determined in different fertilizers, DAP (18:46:0).
ii. To figure out the yield potential of finger millet (variety P224) using 3 different spacing.
iii. To determine the interaction effect between different Crop spacing and fertilizer amounts on growth and yields of finger millet.

1.6 Research Hypothesis

i. A significant difference in the growth and yield of finger millet was depicted (variety P224) at different levels of DAP (18:46:0) fertilizer application.

ii. There is a notable difference in the yield potential of finger millet (variety P224) at different spacing.

iii. The interaction between spacing and fertilizer application levels on growth and yields of finger millet was consequential.

CHAPTER TWO

LITERATURE REVIEW

This chapter examines the literature on finger millet (*Eleusine Coracana* L.) development and grain yields associated with fertilization and spacing in Ainamoi, Kericho County. This chapter also reviews the literature in relation to the study objectives.

2.1 Botany of Finger Millet

Finger millet belongs to the family Poaceae (*gramminae*). Finger millet is a very vital food crop under the small-scale under the cereals category farming system in Africa, especially in the upland areas of Eastern Africa, namely Kenya, Tanzania, Ethiopia, and Uganda, commanding a higher market price compared to other cereal crops like maize and beans. It can be kept for a long time without harm by insects and is particularly extremely nutritious. The crop is a very precious subsistence food product. The plant prepares multiple meals such as porridge, ugali/sima in the diet of the area which is highly recommended because of its nutritional importance for the sick, babies and elderly. It is also commonly used for the production of beer in African nations including Kenya, Ethiopia and Uganda. Today the world's fourth most important crop is sorghum, perlite millet and foxtail millet (Gupta, Gupta, Gaur & Kumar, 2012).

The finer millet is cultivated in over 25 nations, primarily in Africa, according to Dass, Sudhishri and Lenka (2013) and is grown in Asia in the nations of Nepal, India, Japan, Malaysia, China, Afghanistan, Iran and Madagascar, Senegal, Nige, Nigeria and Senegal in the African region. Major producers in Eastern Africa are Uganda, Tanzania and Kenya. Nutritionists see finger millet as being the key to finally solving Africa’s malnutrition problems owing to it being one of the highly nutritious foods among major cereals crops (Midega, Khan, Amudavi, Pittchar & Pickett, 2010). The nutrient value and filling nature of this grain are ascribed to the reality that individuals in finger millet fields can prosper on only one dinner every day. The crop is mainly consumed by marginalized people in Asia and Africa and is, in addition to being sold to provide subsistence producers with extra revenues, ranked fifth in cereal manufacturing in the world's semi-arid areas following sorghum (*Sorghum bicolor*) and Perl millet (*Pennisetum Glaucum*), according to Lule, Tesfaye, Fetene and De Villiers (2012). As demand for the crops grew, caused by erratic pluvial precipitation and decreasing population size, the need to reconsider corn cultivation in order to tackle food insecurity in Kenya was urged. The damaging impacts of Striga weed in lowland fields and the dreaded MLND also turn off prospective maize farmers (Midega et al., 2010).

2.2 Origin of Finger Millet

The annual herbaceous plant *Eleusine Córacana*, better known as finger millet, is commonly cultivated in the arid and semi-arid African and Asian regions as a cereal crop. It is a tetraploid species that has likely developed from its wild relative *Eleusine Africana* and self-pollinating. Finger millet comes from the highlands of Ethiopia and Uganda (Kumar et al., 2016). An approximately 5000 years ago, the earliest known archaeological remains were excavated at Axum, Ethiopia. Highly developed finger millet kinds that are still cultivated in Ethiopia are similar. Fingers millet cultivation extended to East and South-Africa during ironworking expansion some 800 years ago (Lule et al., 2012).

It is now cultivated from Ethiopia and Eritrea to Mozambique, Zimbabwe and Namibia in tropical Africa. The finger millet of western Africa is not very important but is reported from an eastern part of the low rainfall zone, in Niger and in northern Nigeria in particular. Finger millet arrived in India between 2000 and 3000 years ago. It extends to China and

Japan from India through Southeast Asia. It is cultivated on a tiny scale for bird seeds in the United States (Sood, Joshi, Chandra & Kumar, 2019).

2.3 Finger Millet Varieties

There are approximately 6,000 millet variations around the globe with grains ranging from yellow, grey, white and red in colour. Archaeologists say foxtail millet is so ancient that there is no known wild crop of the species today. Over the years, finger millet varieties have been enhanced in the local and international germplasm collections. Among the medium maturing varieties, P224, Gulu-E, Serere and KA-2 have shown a yield potential of more than 2000 kg/ha under good management (Ramashia, Gwata, Meddows-Taylor, Anyasi & Jideani, 2018).

For medium-potential fields above 1,500 m above sea level, the varieties are suggested. IE 1010, EKR-227, and P283, which are recommended for reduced midland regions, are other improved varieties of excellent yield potential. International Crops Research Institute for Semi-arid Tropics (ICRISAT) has also released KNE-479 and KNE-1034 genotypes, which can endure the harsh conditions of semi-arid areas such as Machakos County (specifically the Katangi area) as reported by Shibairo, Nyongesa, Onyango and Ambuko (2014). A preliminary study conducted at the KALRO-Kibos showed that better-elevated yield variants, likeOkhale-1andU-15, were also introduced into the market. The yields can significantly enhance the use of enhanced varieties and better agricultural methods.

Access to more productive finger millets can lead to Kenya's economic development and poverty reduction by offering small-scale farmers access. Not only will producers which adopt the better varieties be able to sell enhanced output, but they can also share seed with other farmers (Daly et al., 2018). The two main improved varieties; P224 and Gulu E are good because they are early maturing, up to 3 months to maturity in warm moderate rainfall areas of Busia and Teso Counties and up to 5 months in cold and low rainfall areas like in Lanet of Nakuru County in Kenya. They are less prone to blast illness of the finger millet. In cold regions and in hot regions, up to waist height, they are also simple to harvest. All the plant heads mature simultaneously. The rates are high and up to 10 bags per acre have been reported on the farms in Busia. The varieties are also easy to thresh as farmers appreciate the good threshing ability, especially Gulu E as reported by (Shibairo et al., 2014). U15 is the main variety produced in Uganda, which is known for its brown head and low height features. The P224 finger millet variety is the most widely cultivated variety in Kenya, due to its elevated yields and early maturity, its resistance to blast diseases and its low height resistance to a shelter.

Table 2.1.

Characteristics of Common Finger Millet Varieties in Kenya

Variety	Optimal production altitude(m asl)	Maturity (months)	Grain colour	Potential Grain yield (in 90 kg/acre)	Special attributes
P224	1150-1750	3-4	Brown	10	Tolerant of lodging and squall disease
Gulu E	250-1500	4	Brown	8	-
KAT/FM1	250-1150	3	Brown	7	Drought tolerant, tolerant to blast and high in Calcium
LANET/FM1	1750-2300	5-7	Brown	7	Tolerant to cold and drought

Source: Handschuch and Wollni (2016)

In Uganda, several finger millet varieties are grown which suits the climatic and Agro-Ecological conditions of the Country. According to Wafula, Korir, Ojulong, Siambi and Gweyi-Onyango (2011), several new varieties of finger millet have been released which include the following: P224 (Pese1) and Seremi 2 in Uganda, U15 and P224 in Tanzania in 2012, KNE 409 and 1098 in Ethiopia and P224 in Kenya the same year of 2012. The new varieties are expected to boost production due to their early maturity and resistance to pests and diseases.

2.4 Significance of Finger Millet

Millet's finger is a significant crop. Poor farmers in eastern and southern Africa who are characterized by low input farming schemes play a key role both in food safety and in nutrition (nutritious products include; mandazi, “Uji” and “Ugali”, crackies, bread cakes, malt which is only comparable to barley in malting quality. It can also be used for beer as well as high food products for special diet needs for children and the sick, good storability i.e. There are no pests and conditions in storage, which means that they are very supreme in the fight against food insecurity; cultivation; revenue is almost doubling maize and sorghum prices; other uses are animal feed, thatching and weaving of baskets). In terms of significance in the millets after the culleness of sorghum, Perl millet and foxtail millet, finger millet is ranked fourth worldwide (Ghimire, Joshi, Dhakal & Sthapit, 2018).

Approximately 65,000 ha (Kenya), 437,000 ha (Uganda) and 305,000 ha (Ethiopia) are cultivated in crop returns varying from 500–1,000 kg / ha to a potential > 5,000 kg / ha (Lule et al., 2012). Despite its significance, the research and development of Finger Millet have been overlooked, and ICRISAT (2013) states that finger millet is very essential. Minor millets are cultivated in East and South Africa, South Asia and Central America.

Due to its medicinal nature and elevated dietary value, the crop is very helpful to individuals with diabetes and increasing kids because it is very rich in nutrients such as Ca, P and Fe although mostly eaten by the less fortunate individuals. In addition to immediate human consumption, its grains are used to prepare cakes, pudding, sweets, and the germinated grain is malted for beer production and infant feeding. It is also suggested for females who are pregnant. The crop is also chosen for adolescents of varying ages as an extremely nutritious food. Udeh, Duodu, and Jideani (2018) have stated that occupants of the finger millet cultivable fields could be found on a single meal per day. Due to its storability, finger millet is also used in the manufacture of fodder for animal feeding, particularly during dry periods when fodder is scarce. Kenya's main producing regions are Kakamega, Kisii, Bomet, Kericho, Nandi, Nakuru, Kuria, Migori, Machakos, Kitui, Baringo and coastal regions (Neha & Sarita, 2017).

While finger millet is essential to the lives of millions of poor Africans, study into these plants falls short of plants such as corn, wheat and rice. It was less crucial because research and development were gradually neglected, leading in the absence of adequate and modern manufacturing techniques according to Plaza-Wüthrich and Tadele (2012). Finger millet has been decreasing for over 30 years in Kenya compared with other cereals such as maize and wheat, but the industry now reports that the returns from enhanced species have risen from 500-780 tonnes a hectare, to an increase of between 3.5 and 4.2 tons a hectare. Kenya's West Rift Valley areas extending into Uganda is second after Karnaka in India as the world's second-biggest finger millet cultivation region (Karuppanchetty et al., 2014).

In the last decade, Kenya's trend has changed because of renewed research into traditional plants leading to the introduction and development of high yield, drought-tolerant and enhanced varieties. Millet remains for millions of the world's poorest individuals, although they are scarcely used in the West, the main source of electricity, protein, vitamin and minerals. It is therefore appreciated for its nutrition and cultural uses, such as traditional socializing liquors as reported by Shobana et al. (2013). It contains a healthy content of inexpressible carbonic hydrates and is also used for malnutrition, diabetes and AIDS patients because sugar is slowly released from the millet-based diet. The amino acid methionine that is missing from the foods of several disadvantaged persons living on starchy staples such as the rice, maize, and thus is particularly precious.

The grain is made into a festival drink in many parts of Africa and potential for brewing industries as well as grounded and cooked into cakes, “mandazis”, “chapatis”, porridge and when fermented, Finger millet produces excellent fodder for livestock and offers up to 61 per cent more than other cereals like corn, wheat and sorghum for livestock than complete digestible nutrients. Mothers use finger millet flour as a source of energy by creating Ugali for the family for the purpose of childcare, breastfeeding and for pregnant women (Neha & Sarita, 2017).

The remains of the plant may also be used for the production of stalking traditional roofs and the building of walls for traditional granaries. Surplus production may be sold to the local and milling industries to increase farmers ' incomes and thus enhance their livelihoods. Finger millet can be used particularly among African nations for international trade, where it is produced as a conventional food crop. Countries within Common Market for East and Southern Africa (COMESA) region can benefit greatly on finger millet trade in the trade block popularization under COMESA. One of the COMESA objectives is to strengthen the regional markets for trade and food security competitively (Handschuch & Wollni, 2016). Therefore, farmers must be encouraged to boost acceptance for this enhanced finger millet varieties. Small farmers ' empowerment can significantly boost food production because they make up over 75% of the agricultural produces in the developing nations (Hosseini, Nejad & Niknami, 2009).

These small scale producers are characterized by intensive farming on smallholdings and when empowered, can contribute greatly to agricultural production. A success story of empowering small scale farmers was demonstrated by Vietnam, where the country could not feed its population by 1970 leading to reliance on food aids but after empowering the small scale holders on rice production, the country is now the second world-leading exporter of rice. The Vietnam smallholders achieved this production from an average holding of two acres farm. Kenya can learn from Vietnam and empower small scale farmers with production technologies that will lead to increased production and achieve the most desired food security for its population. Establishing factors that can assist farmers to increase adoption of production technologies may lead to enhanced food production and improved livelihood (Mutiga, Gohole & Auma, 2011).

Farmers' adoption of improved finger millet varieties and the related technologies for continued use, go through a number of individual assertions as they relate to the new technologies. The farmers require to be given accurate information on production technologies especially on quality inputs (Muricho, Kassi & Obare, 2015). Availability and access by farmers to quality seeds contributes significantly to increased crop production. Quality agro-inputs include seeds, fertilizer and chemicals and each contributes to enhanced production. A seed quality greatly contributes to improved production, therefore, it is the most important basic inputs of crop production. The Kenya government recognized the importance of seed quality and initiated a regulatory body called Kenya Plant Health Inspectorate Service (KEPHIS) in 1998 under the Ministry of Agriculture to regulate the quality of seeds offered to the farmers. Under government standards enforced by KEPHIS, seeds offered to farmers have to meet the minimum standards set by the government and offering seeds to farmers that fall below these standards is a violation of laws and one can face prosecution. Seed sellers are required to register and be licensed by KEPHIS and maintain and renew their license annually to ensure compliance to standards (Munyi & De Jonge, 2015).

2.4.1 Nutritional Properties

It contains 5-8% proteins, 1-2% ether extractives, 65-75% carbohydrates, 15-20% dietary fiber and 2.5-3.5% minerals. The highest amount of Ca (344 mg %) and Potassium (408 mg %) of all the cereals and millet are found in finger millet and therefore it has been experimentally proved as one of the most nutritious cereals. The cereal contains mainly unsaturated fat and has low-fat content of (1.3 %). Finger millet in 100 grams roughly has on an average 336 Kcl of energy in them. Finger millet also, however, contains phytates (0.48%) and, polyphenols, tannins (0.61%) trypsin inhibitory factors and dietary fibre, which were once considered as “anti-nutrients” due to their metal chelating and enzyme activities (Shobana et al., 2013) but nowadays they have been referred to as nutraceuticals. Since finger millet is non-glutinous, it is safe for consumption by people suffering from gluten allergy and celiac disease. It is non-acid forming, and hence easy to digest. Finger millet is rich in amino acids (Tryptophan, Threonine, Valine, Isoleucine and Methionine).

Millet's dietary profile is far above rice and wheat by any food parameter relative to the two bowls of cereal in terms of its mineral content. Most millets have greater fibre than the reported rice and wheat according to Gull, Jan, Nayik, Prasad and Kumar (2014).

Calcium is thirty times more in finger millet than rice; all other millets have at least twice as much calcium as the rice as the writer has described. In their iron contents, foxtail and millets are so wealthy that rice is not present at all. While a micronutrient such as Beta Carotene is sorted by most of us in pharmaceutical pills and capsules, it is easily available in a wealth of millet. Ironically, this valuable micronutrient has none of the privileged rice (Devi, Vijayabharathi & Sathyabama, 2014). Nutrient to nutrient, in this fashion, shows that every single millet is extraordinarily superior to rice and wheat and therefore is the panacea to the malnutrition effects which is evident among a big percentage of the Indian population.

Table 2.2.

Nutritional Components of Millet and "Big" Cereal (grams)

Small Millets	**Grain Type**	**Energy**	**Carbs**	**Proteins**	**Fat**	**Dietary Fibre**	**Ca**	**Fe**	**Thiamin**	**Riboflavin**	**Niacin**
	Foxtail	351	63.2	11.2	4	17.62	31	2.8	0.59	0.11	3.2
	Barnyard	300	55	11	3.9	13.7	2	8.6	0.33	0.1	4.2
	Kodo	353	66.6	9.8	3.6	17	35	07	0.15	0.09	2
	Little	329	60.9	9.7	5.2	15.08	17	0.3	0.3	0.09	3.2
	Finger	336	72.6	7.7	1.5	18.8	350	0.9	0.42	0.19	1.1
	Common	364	63.8	12.5	3.5	12.4	8	0.9	0.41	0.28	11

Large Millets	Pearl	363	67	11.8	4.8	20.4	42	1	0.38	0.21	2.8
	Sorghum	329	70.7	10.4	3.1	14.2	25	0.4	0.38	0.15	4.3
	Wheat	348	71	11.6	2.0	12.9	30	0.5	0.41	0.1	5.1
	Rice	362	76	7.9	2.7	5.2	33	0.8	0.41	0.04	4.3

Source: Kumar, Tomer, Kaur, Kumar & Gupta (2018)

2.5 Challenges in Finger Millet Production

The finger millet seed does not germinate inland without sufficient humidity to promote seedling development, which is usually dormancy-free. Soils are susceptible to drought, but mature crops sleep in brief periods of drought and generate tillers in favourable circumstances. Plants heavily reap and root from the lesser nodes and protect them from soil erosion. The time to flower is between 50 and 120 days; the whole crop cycle is between 3 and 6 months. The inflorescence flowering lasts for eight to 10 days and the branches flower from top to bottom. Finger millet is predominantly self-pollinated, without-crossing of about 1 per cent. Heavy growing rain decreases seed setting. Finger millet follows the Krebs cycle of the photosynthetic pathway (Taylor, 2016).

2.6 Ecology of Finger Millet

In eastern and southern Africa, finger millet is most commonly grown at 1000 to 2000 m and at an average temperature of 23 ° C from sea level to about 2, 500 m altitude. It is mostly cultivated during the growing season in regions with 750 to 1, 200 mm of rainfall. The minimum rainfall for finger millet is 300 to 500 mm, but because of their superior drought tolerance, sorghum and pearl millet are more frequently cultivated below 750 mm. Finger millet is a short-day plant, mostly near to 12 hours, with a critical day length. Finger millet develops on a variety of soils but prefers fertile, well-drained, and sandy soils with decent ability to hold water. It prefers a pH of 5 to 7 but tolerates very alkaline soils and does not tolerate waterlogging (Neha & Sarita, 2017).

2.7 Propagation and Planting of Finger Millet

In a region of elevated rainfall, finger millet can be grown as well as irrigated circumstances in well-drained soil as a transplanted plant. All crop cycles in separate parts of the nation are beneficial for its glow. It is recommended that the output is smaller or greater than the optimum population. It is suggested to use 25 x15 cm (25 cm from line to 15 cm from plant to plant range) for the most advantageous population (Satish et al., 2015).

Finger millet from seed is propagated. The weight of 1,000 plants is between 2 and 3 g. Fields are made by hoe or plough drawn from animals. Fields may be cultivated at the start of the rain, plants may germinate, and crops may be cultivated a second time or as many as six times before the cereal crop is cultivated to control weeds. Harrowing also helps to decrease weeds before planting. Seeds are transmitted behind the plough in lines. When the plant is transmitted, seed yields up to 35 kg/ha can be used; in a sequence, seed levels are only 3 to 10 kg/ha.

Seeds are seeded in rows from 2 to 3 cm in-depth, 20 to 35 cm in a row. Seedlings shall be diluted to 5 to 12 cm in a row as quickly as convenient. Sometimes seeds are germinated in nurseries in India and when they are 3-4 weeks old seedlings are grown in the field. Fresh cereal grain is provided well before finger millet matures directly, although it is intensive in labour. Finger millet can alternatively be seeded or plant 1 to 2 weeks prior to the anticipated rainfall. According to Satish et al., (2015), small farmers in Africa, most of who cultivate finger millet and intercrop with other grains, pulses or herbs. In Ethiopia, finger millet is cultivated solely.

Line Sowing: Better than broadcasting sowing. The better distinction between weed and crop facilitates organic weed management. The spacing between lines is frequently kept between 22 and 30 cm and between 8 and 10 cm in rows. The seeds are planted in the soil approximately 3 cm deep.

Drilling in rows: Seeds are sown directly in untreated soil by using a direct seed drill. This method is used in conservation agriculture.

Transplanting the seedlings: The seedlings are raised and transplanted to the main cultivation area in the nursery bed. During transplantation, levelling and watering of beds are required. Seedlings are transplanted into the field at the age of 4 weeks.

Selection of healthy seeds without damage to birds or insects, seedlings that could be well served in the event of pest attacks or diseases. Seeds are prepared to be seeded, threshed by removing all the admixtures, such as glumes, rachis and peduncles (as long as stored on the head). This can be achieved through twisting and sometimes sieving. It also removes tiny seeds and lightweight. A 10 per cent salt solution is used to distinguish excellent seeds from poor seeds by a quick, simple and effective seeding selection technique. The salt solution improves light foreign material floatation. Well heavy seeds and gallstones fall to the ground. The floating section is decanted and dismissed, and the submerged section is floated once or twice, after which the proper plants are rinsed with smooth water and the surplus salt is removed. This is then sun-dried and the cake is hand-crafted (Satish et al., 2015).

Preparation of finger millet early is suggested because Millet needs fine seedbed appropriate for tiny seeds for proper germination, right crop demographic density and efficient weed control. Early preparation is suggested before planting. After the first ploughing, it is advisable to plant the soil with either oxen or tractors. Farms must split the clods so that they provide a soft seedbed if they are used to prepare jembes (hand hoes). Planting by either drilling the necessary or desired furrows, by the use of a panga (cutlass) or by the use of hoes in mountains should be performed before or at the beginning of the rain. A variety of spatials is frequently used for single cultivations: Perl millet: 15 cm between plants and 60 cm between rings are frequently used, while foxtail and proso millet are usually distinguished: 10 cm between plants and 30 cm between ranks (Neha & Sarita, 2017).

2.8 Soil Fertility and the Need for Fertilizers on Finger Millet

Soil fertility refers to the intrinsic capacity of a soil to supply nutrients to plant. On the other hand, Integrated Soil Fertility Management (ISFM) refers to a set of agricultural practices adapted to local conditions to maximize the efficient use of water and nutrients to upgrade agricultural productivity. ISFM strategies Centre on a combination of the use of mineral fertilizers and locally available soil changes such as lime, phosphate rock and organic matter (crop residues, farmyard manure, compost and green manure) to replace lost soil nutrients. This will improve both soil quality and efficiency of fertilizer use and other agro-inputs (Vanlauwe et al., 2015).

The decreasing per capita food output in Sub-Saharan Africa is considered to be the most serious bio-physical root cause. Due to elevated population development and drought migration, food shortages and over-cropping have accelerated agrarian property degradation. The primary variables leading to nutrient losses are wind erosion of the soil, water and liquidation of N and P. Nutrient losses in Africa, particularly from erosion, vary from 10 to 45 kg per hectare of NPK annually (Vanlauwe et al., 2015).

In the lack of an internal nutrient input, continuous development of soil constantly decreases the soil nutrient reserves (macro and micronutrient), leading in bad cropping returns, through reduced harvests, erosion, leaching, and gaseous emissions. Nitrogen and phosphorus are extremely small in tropical soils. Phosphorus is one of the most necessary ingredients for cultivation in most tropical soils. The component is very important for millet since it stimulates development, initiates flora, fertilization and creation of grains, and strongly stimulates the effectiveness of the absorption of other nutrients (Udeh, Duodu & Jideani, 2018).

Its demands in big amounts are elevated and cell divisions very fast in youthful organisms, such as root and shot advice. N and P, with an annual loss estimated at 42 kg N and 3 to 4 kg P / ha for 30 years of cultivation, are the two most depleted nutrients. Around two-thirds of the workforce in Africa relies on their survival on cultivation and all African nations except Mauritius, Reunion and Libya have annual adverse nutrient balances (Turner, 2016). Declining soil fertility in Sub-Saharan Africa (SSA) is largely attributed to poor soil management practices (Sathish et al., 2017).

The impact of decreased land fertility has been shown to decrease crop yields, which is especially evident in Africa where food safety issues are most severe. The small levels of fertilizer use and decrease in soil organic matter contribute the most to land-fertility failure within the region with insufficient focus on plant nutrient research. Declining soil fertility in Kenya has resulted in a drop in soil efficiency, which is why property owners are urged to use technology for improving the soil. Such issues are an insufficient and ineffective use of crop inputs, such as fertilizers in Kenya, such as soil erosion, constant agriculture, decreased efficiency of land, demographic pressures on land and poor incomes (Patel, Patel, Mor & Chaudhary, 2018).

Land availability constraints and demographic pressures partly contributed to the decline in yield growth and soil fertility. The traditional techniques for renewing soil fertility such as slash and burn and long-time fallowing are not as feasible as they once were due to the increasing population. The need for subsistence means that soil can no longer be removed for significant periods from manufacturing for the purpose of regenerating nutrients. In the soils of Africa, nutrient benefits are primarily due to implementation of mineral fertilizers, organic matter mineralization and rainfall nutrient accumulation. Due to their elevated profitability, fertilizers are mainly used in money and plantings and generally export to overseas currency. The unfavourable cost relationships and economic limitations of producers on cultivation and fertilizer plants (Julio & Carlos, 1999) make food plants less fertilizer-free. Improve soil productivity in SSA from ancient moments and this involves the use of agricultural manure, the conversion of nutrients and legumes to replenish soil fertility (Mugendi, Abuli & Mugwe, 2017). Finger millet-based crop rotations or relay cropping are common cropping practices in South Asian countries, involving maize-millet, potato-millet and groundnut-millet (Srinivasarao et al., 2012).

In Africa, plant rotations of finger millet include, as recorded from East Uganda, beans-cassava-cowpea-groundnuts-cotton, beans-cotton-cowpeas and beans-cotton-maize. The significance of crop rotation is that the remaining fertility from the earlier plant to the next plant is facilitated. Compared with organic fertilizer, the observatory button showed that, when the fertilizer was provided, millet benefitted more from the prior crop's remaining fertilizer. Based on a study conducted in eastern Uganda by Ebanyat et al. (2010) found that finger millet yields following legume crops (cowpea, green gram, groundnut, mucuna, pigeon-pea, and soybean) were higher compared to continuous finger millet cropping.

N advantages from leguminous crop residues have however reduced with the progress of the season. The farmers were unwilling to use some of their legumes in the plant rotations because they did not know how marketable or useful they might be, particularly for fodder for intercrop mucuna. However, when the earlier crop was a non-legume, the remaining N advantage to finger millet proved to be small. Selection of appropriate crops in finger millet based crop rotations is therefore very important in order to utilize the residual nutrients and to obtain N credits for finger millet from the previous crop (Ebanyat et al., 2010).

Some farmers in parts of Kenya, as reported by the Ministry of Agriculture (2013) in Bomet, have indigenous technical knowledge (ITK) on the production of finger millet. The traditional way to cultivate finger millet includes opening and propagating virgin soils by cutting plates or sods 25 cm tall to dry the grass. If the sods are totally washed, they are piled upside down and burnt in the conical form at different points throughout the area. The brown burned soil then spreads over the excavated region, blended together into a good seedbed and seeds finger millet. The practice is widespread in Bomet, Bureti and Kericho (Kirui, Alakonya, Talam, Tohru & Bii, 2014). According to farmers, high yields and quality of finger millet are obtained by using this indigenous technical knowledge (ITK) and the practice also reduces weeds apparently. Field extension staff suggests that burning assists in weed control improves soil fertility and controls soil-borne diseases (Kericho District Agricultural Office Report, 2015).

The practice of burning soil before planting crops is not unique in Kenya. In high altitude areas of Ethiopia, a traditional practice called *Guie* (soil burning) was reportedly practised when growing barley on vertisols (Kirui et al., 2014). After one season of finger millet growing in Bomet or other districts practising the same, the land is abandoned for at least 4 years. The practice destroys organic matter and, however, the practice still continues despite an advisory to deter the practice. The practice is labor-intensive, time-consuming, destructive and unsustainable and requires farmers to have a large piece of land for continuous production. Land subdivision due to population increase does not allow for large-scale ownership. Therefore, there is a need to find an alternative to the burning of soil for the production of finger millet and identify means of reclaiming abandoned lands (Kusia et al., 2015).

2.9 Nitrogen and Phosphorous Effects on Finger Millet Yields

Nitrogen, Phosphorus and Potassium are the three major essential elements required for plant growth in relatively large amounts since the deficiencies of nitrogen and phosphorus are common. One of the major setbacks farmers face is low soil P and cultivation induced degradation. Although finger millet is very important, the crop has not been given enough research attention and has limited information on P management. The most essential nutrient for the life of plants whereby without adequate supply they cannot reach their maximum yield is phosphorus (Nafuma, Kitur, Mahagayu, Wanyera & Kipkemoi, 2010).

Adoption of proper agronomic management practices to existing varieties can lead to achieving potential yields. Soil nutrients become exhausted due to leaching of nitrogen, fixation of phosphorus, soil erosion and removal by crops. To maintain high crop production level, the nutrient status of the soil has to be supported through crop rotation, the addition of manures or application of inorganic fertilizers. In any agriculture scheme, inorganic fertilizer is very important because it provides the necessary nutrients for instant crop application in easily accessible types. The nitrogen deficiency is responsible for crude protein, decreased matter and grain yield. According to the Fertiliser-usage Recommendation Project Sorghum (*Sorghum bicolour* (L) reacts to modified fertiliser and can boost output by more than 50% (Nafuma et al., 2010). However, owing to altering economic conditions in Kenya, a study of this advice is important. Application to potassium, phosphorus and nitrogen in Africa and the Middle East as start fertilizers have been reported to be beneficial for vigorous early growth (Kubure, Cherukuri, Arvind & Hamza, 2015).

Plant performance and yield in beans increase with nitrogen doses. Could it be the same for finger millet? Fertilizer placement at correct depth promoted growth and development of crops, and the plant growth and yields increase with increasing nitrogen and phosphorus fertilizer treatment.

Fertilizer placement at 10 to 25 cm depth has promoted growth and development of roots and shoot of French beans. The contemporary study was designed to study the response of finger millet crop to nitrogen and phosphorus supplied as DAP (18:46:0) as measured by plant height tillering, seed weight and grain yield of the finger millet under conditions of Kenyan highlands.

2.10 Yields and Yield Factors of Finger Millet

The importance of finger millet crop particularly in low input farming systems by resource-poor farmers in eastern and southern Africa is derived from its nutritional value (nutritious products like; "Uji" and "Ugali", bread, cakes, crackies and mandazi). Malt (simply similar to malt barley and suitable for elevated value food products for kids and ill people's unique nutritional requirements); excellent storage and use for beer (without illnesses or storage spoils, therefore suitable for food safety policies), culture, earnings (fetches more than double the cost of corn and sorghum); other utilizes (stoning and basket food); Therefore, for the markets in which it grows, the returns of Finger Millet are of financial significance. The crop in Kenya is about 65,000 ha, in Ethiopia about 305,000 ha and in Uganda, 437,000 ha with yields range between 500 and 1,000 kg/ha with a capacity of over 5,000 kg/ha (Kumar et al., 2018). In spite of its importance, some authors have argued that the crop has been omitted in terms of research and occurrences (Grovermann, Umesh, Quiédeville, Kumar & Moakes, 2018).

The lack of information on the correct fertilizer levels to apply and the cost-effectiveness of farm inputs has led to low production of the crop while there is a very high demand in market for the crop coupled with the threats posed by the new lifestyle diseases like Diabetes which calls for the patients to consume products from Finger Millet such as brown *Ugali* and porridge that slowly releases its calories.

Comparing millet yields to those other grains in the area is generally good. In Uganda, for example, a threshed yield of 1,800 kg per hectare is considered as average. Yields may be about 1,000 kg per hectare, and on irrigated sites, a normal average is more than 2,000 kg per hectare in India on reasonable dryland sites. Yields of 5,000 kg per hectare have prevailed under ideal irrigated conditions. Similar high yields have prevailed in Nepal even under rainfed conditions as reported by (Luitel, Siwakoti & Jha, 2018). It is important to get amino acid methionine, which is restricted to the diets of hundreds of million impoverished people, who reside on starchy foods like cassava, plantains, fruit polishing or corn. Finger millet can be mashed, padded or poured into cakes. The cereal is produced in Nepal and sections of Africa as a fermented beverage (or beer).

The straw from finger millet is used as animal fodder. It is also used for a flavoured drink in festivals (Grovermann et al, 2018). In comparison with rice and wheat, millets have dietary parameters far ahead in terms of their mineral content. There is more fibre than rice and wheat in every millet. In comparison with other millet with at least twice the quantity of calcium, finger millet has 30 times more calcium than rice. The foxtail and millets are so wealthy that grain has no iron content at all in the breed. Millets deliver a variety of necessary micronutrients in pharmaceutical pill and capsules, such as beta carotene. Ironically, this valuable micronutrient contains zero amounts of the most privileged rice. In fashion, nutrient to nutrient, every single millet is extraordinarily supercilious to rice and wheat hence, the solution for the malnutrition that affects a vast majority of the population as reported by (Gull, Jan, Nayik, Prasad & Kumar 2014). In view of the nutritional value of Finger Millet, its yield-related factors must be managed so that its yield potential can be fully realized.

Table 2.3

Top 10 World Millet Producers in 2018

S/No.	**Country**	**Production(Tons)**
1	India	10,910,000

2	Nigeria	5,000,000
3	Niger	2,955,000
4	China	1,620,000
5	Mali	1,152,131
6	Borkina Faso	1,109,000
7	Sudan	1,090,000
8	Ethiopia	807,056
9	Chad	582,000
10	Senegal	572,155

Source: Sakamma et al., (2018)

2.11 Storage

Finger millet seeds are exceptional and rarely assaulted once they have been eaten by insects or moulds. It is famous for its excellent shelf life and can be held untreated for up to 10 years. Some sources state the length of storage for up to 50 years under very excellent storage circumstances. Grains can dry up to a moisture content of 10-12 per cent. Finger millet is essential for policies for the avoidance of risks to famine in bad agricultural societies because of its lengthy ability (Grovermann et al., 2018).

If the content of humidity in farmhouses is preserved optimally, plants may remain in farmhouses for many years as a finger millet for more than five years owing to the small risk of insect harm, as suggested by Mgonja, Lenne, Manyasa and Sreenivasaprasad (2007). It can be maintained without any negative impact on grain quality for more than two decades. The millet meal and its products also have an excellent shelf life. Apart from India, foxtail millet, proso millet and barnyard millet have been common food grains for many decades in many nations of Eurasia including China and Japan. The plant is prepared for storage after threshing and washing. The seeds are well stored for five or more years. In Tanzania, the plant has remained without damage for up to 10 years. The cereals are sometimes blended with ash or cooked before processing.

2.12 Weeds, Pests and Diseases and Yield

For the production of finger millet, the main biotic issues are weeds. Its seeds are therefore very small and lead to relatively slow growth in its early stages, making it a very weak competitor with nutrient weeds (Ojulong et al., 2011). Finger millet is a grain plant which is brief and expands at maturity to about 2 feet. Weeds competing for light, nutrients and water are the unfriendly number one under bad plant leadership circumstances. The depletion or decrease of these significant assets often leads to a complete failure of this crop. Some of the plants can develop bigger than finger millets and compete strongly for light. Therefore, the plant is unable to make complete use of its capacity in the production of its own meat, which leads finger millet plant to etiolated crops.

In Eastern Africa however, the closely related species *Eleusine indica* (common name; Indian goosegrass) is a severe competitor of finger millet especially in early growth stages of the crop and when broadcast seeding is used instead of row seeding (as often the case in East Africa), the two species *Xanthium strumarium*, which is animal dispersed and the stolon growing species *Cyperus rotundus* and *Cynodon dactylon* are important finger millet weeds (Mgonja, Audi, Manyasa & Ojulong, 2011).

One of the most expensive activities faced by finger millet farmers is weed management which can normally take up to 50% of the total labour cost in the crop management operations. This has become a constraint in the household area that can be put under finger millet production. Removal of weeds in finger millet field can be done mechanically by hand, though it is a very tedious and costly exercise compared to chemical application. Integrated weed management is the only feasible operation since there is no single best way of eliminating weeds from the field except the combination of cultural and chemical weed control styles. Even when the chemical method is applied, weeds also need to be pulled mechanically by hand to ensure the crop harvested is clean without contaminants. Hand weeding is more prevalent with resource-poor farmers. It is commonly undertaken by women and children although it can also be done by men. When it involves children, it leads to drudgery and child withdrawal from school at the wedding peak season. This is a very costly exercise in terms of the time involved however if it is utilized effectively, weed control will be done properly leading to an increase in farmers' production and income.

Bird predators such as Quelea in East Africa are the most significant finger millet pests. The rosé bud borer and pit worm (*Sesamia inferens*) are the most important insect plagues in the culture of the finger millet (Upadhyaya, Reddy & Sastry, 2008). *Sesamia inferens* interventions include disposal of contaminated crops, the destruction of stubble, the rotation of crops, chemical insecticide control, biological interventions such as pheromone traps, or biological control of the pesticide by antagonistic bacteria, such as *Sturmiosis inferens*. Finger millet is assaulted by several plagues, which can lead to very small returns or no total returns if not monitored. Borers, armyworms and miners are the primary diseases frequently seen by finger millet producers that have harmful impacts (Table 2.4).

Table 2.4

Common Pests of Finger Millet

Pest	Effect/Damage On Crop	Common Control Measures

Spotted Stem borer (*Chilopartellus*) Millet Stem borer (*Coniesta ignefusalis*)	Caterpillars bore into the stems of millet and attack young plants causing damage known as "dead hearts"	Application of insecticides such as Thuricide or botanicals such as neem and pyrethrum extracts when caterpillars are young Observing field hygiene
African armyworm (*Spodoptera exempta*)	Caterpillars eat the above-ground parts of young plants leaving only the bases of the stem	Use of insecticides such as Thuricide or botanicals such as neem and pyrethrum extracts when caterpillars are young Observing field hygiene
Millet head minor (*Heliocheilus albipunctella*)	Caterpillars mine into the seeds of millet heads damaging the millet panicle	Deep plough to display residual larvae and pupae to natural enemies and desiccation. Late plant(by 2 weeks short cycle millet varieties

Source: Ministry of Agriculture - Crops Extension Hand Book (2013)

Finger millet is not considered to be very susceptible to disease or plague. However, fungal pathogen Magnaporthe grisea is the most prevalent finger millet blast disease induced by a fungal pathogen, which can trigger serious damage locally, particularly if it has not been treated or monitored. In Uganda, losses of the output until 80% in poor years have been recorded. The pathogen causes the leaves, the throat and ear rot to dry.

Symptoms of photosynthesis can be drastically reduced, photosynthesis translocations and grain filling, therefore, reduce output and grain quality. Finger millet blast disease can also affect the Gramineae family, as its strongly associated plants are; *Eleusine indica, Eleusine africana* or *Digitaria spp, Setaria spp*, and *Doctylocterium spp*. The use of a mixture of techniques such as cultural interventions, chemical therapy and the utilization of resistant plants can control finger millet blast disease. Cultural interventions proposed by ICRISET for Eastern Africa for controlling millet finger blast include; crop rotations of non-hosted plants, like legume plants, profound ploughing in infected areas under the finger millet straw, soil cleaning after use to avoid pathogen spreads to non-infected areas, weed control, weed management, and weed control to decrease diseases by weed visitors (Hrideek & Nampoothiri, 2017).

Direct spraying, for example with the active ingredient P*yroquilontryclozone*, of systemic fungicides or seed dressings such as testcyclozole can be chemical measures. The fungus *Helminthosprium nodulosum*, which is a leaf blight, is another relevant pathogens in finger millet culture. Various illnesses that are reinforced by the prevalent weather conditions attack the finger millet. Check procedures include opposition to varieties or field hygiene, the use of crop rotation, and field crop management. Meldew, blast and smuts include some of the most prevalent and most prevalent farmers ' illnesses (Chandrashekar, 2010).

2.13 Spacing and Seed Rate

Seeding frequency and distance between rows are correlated. When people are too many, crops compete and lodge often. If the population is too small, a producer will waste room and decrease output. In general, row planting has numerous benefits as opposed to broadcasting. Earlier research on finger millet plant population studies showed that most vigorous finger millets were reported when finger millet was planted at 20 to 30 centimeters, and the seed rate was 10 to 15 kg per hectare. Finger millet planting in rows gives the highest grain output in comparison with broadcasting. The finger millet seed technique is diffused in the main production fields (Shinggu et al., 2009).

Weed development, which is a challenge in plant leadership and as such needs heavy labour input from seed sowing to harvest, is a significant constraint on broadcasting on the ground in finger millet manufacturing. Thus it is one region that should be regarded for improved productivity and manufacturing of finger millet to determine the optimal seed frequency and interline spacing for finger millet. There are some basic ideas which should be regarded in order to comprehend the effects on the output of individual maize crops by their positioning relative to their neighbours. The ideas include plant institution, population, row spacing, interplant rivalry and the division between the output elements of photosynthesized assimilates (Rodenburg & Johnson, 2009).

Some concepts contribute to the quantity of row space allocated to a particular plant, and others are assessed as having an influence on the final yields of each plant (Kumar, 2018). In the past 80 years, the farming sector has been investing in the precise way that the crops are placed in the furrow of their machinery and equipment: an environment sentence now described as' singulation.'

Researchers, farmers and manufacturers proposed that standardized plant distributions can enhance and safeguard final output in the line. This evaluation aims at taking these ideas into account as they add to the personal room and financial element of a plant. Many authors examined the impact that variation in the spacing of different plants has in the last century.

The maize efficiency in single-plant-hill hill schemes compared to maize grown in multiple plant areas over comparable communities has been examined by Sarkar, Paul and Hossain (2011). The single-story tower layout required smaller lines and reduced distance between consecutive hills in the row. The median distinction between single-storey mountains and multi-story mountains with specified densities overall years compared to those of one-story mountains was 5.4%. The writer observed that, over the years, the rise in the output of grain by single plant-coverings originated from bigger and more flowers per crop. Ironically, he said in his debate that there is not much probability of manufacturers ever adopting that technique in business maize manufacturing. Contrary to Sarkar et al. (2011), yellow producers have started trying to enhance seed spacing by increasing planting rates, and they have not yet reached their feasibility.

Many years after the move to a hill with one plant, Andrade et al. (2019) tried to determine whether overall returns might grow due to more precise seed placement with a row. Their findings showed that the spacing variation within a row (measured in normal deviations) had a greater impact on the ear output than on the general output of fruit when their stands surpassed the default standard of 4 cm, which is high accuracy. Recent information indicates that the output could enhance if the amount of accuracy is adopted by a range of 213 to the 4 cm stage (from 6.6 cm standard deviations) to 1,205 kg/ha (from 18.4 cm standard deviations). However, they state that under certain climatic and soil conditions improved planting precision may not increase yields. Hörbe et al. (2016) explored the consequences for the finger millet and later seed output indicators of population density and comparative age. Their research was carried out at five sites in Minnesota in 2009. Ten hybrid plantings were cultivated at multiple densities of 12, 300 to 199, 900 plants/ha, comprising 5 distinct ripening organizations. Each mixture was subdivided into the stressful environment, partial and non-water conditions. Their results showed a close and positive link between grain yield and harvest indices. Their information also shows that the comparative harvest index is decreasing with the growing plant population. This is applicable to the inter-row plant distance. However, the effect of this population on the harvest index varied greatly from plantation to plantation with respect to the amount of water stress.

For instance, the population decreased from 12,300 to 98, 800 plants/ha in the interior of the row. Unstressed conditions have led to modifications in the minimum harvesting index between 0.44 and 0.42. On the other hand, during the season, during the same densities, the harvesting indices changed from 0.40 to 0.12 and from 0.41 to 0.01. Thus it appears that the amount of space within a plant is less important in precipitated environments (Hörbe et al., 2016). More spacing, on the other hand, also enables greater competition between cultivars and weeds.

As a consequence, crop development slows, and its grain returns drop because the development variables are not used adequately but waste clearance, ground disruption and equipment costs are decreased. The population of plants has either asymptotic or parabolic yield relations. The result increases linearly with the increasing population over the reduced age spectrum in the asymptotic relationship (Hrideek & Nampoothiri, 2017). In a parabolic relationship, however, the total return decreases in the higher population and the optimum value is recognizable. With a growing plant population, both biological and economic output improve to an optimal extent and the finest spacing and economic output reduces (Mohaddesi, Abbasian, Bakhshipour & Aminpanah, 2011).

In Canada, the effect of the variability of the intra-row distances on the productivity of finger millet was studied by Moaveni, Afshar, Farahani and Maroufi (2011), and non-mechanical factors that could affect the uniformity of the by-plant yield were examined. During the years 2007 to 2009, two experiments were conducted. One involves the establishment of likewise inhabited stands with varying degrees of stand variability and variations in seedling size. They showed that the output was largely affected by 1 m long with in-line gaps and decreased by 2 meter long gaps, respectively, of 2% and 12 per cent.

The consistent size of the seedling often resulted in higher yields, however, the nearly simultaneous ontogenetic effect of the plants was noticeable. Their second experiment revisited the impacts on grain output of single and multiplant mountains. They discovered on averaging that the output was not reduced until more than two crops were planted on a mound.

CHAPTER THREE

MATERIALS AND METHODS

This chapter shows the method used for conducting the research. This section provides the place of the research, the layout, the climatology, the information collection, results and plot layout.

3.1 Site Description

3.1.1 Location

The research was conducted in Ainamoi Sub-location, Ainamoi Division in Kericho East Sub-County which lies at an altitude of 2, 133m above sea level. The plot lies at 0 23^0S and 34^0 $40^{'}$ E with undulating slopes to the North East of Kericho Town.

Figure 3.1 Location of Ainamoi

3.1.2 Climatology of the area

Temperatures range between 13^0C to 28^0C with low temperatures sometimes experienced below 10^0C especially during the coldest period in the month of July. The area falls climatologically into the UM2 zone (Kirui et al., 2014). The soils are dark reddish in colour and sandy loam texture, acidic and with medium levels of pH, organic matter due to biomass decomposition. The soils are moderately fertile, with low phosphorus levels. The annual average rainfall ranges from 1,300 to 1,800 mm which is bimodal with short rains which starts from the beginning of March and ends in late August while short rains begin from mid-September and goes up to mid- December. Rainfall is well distributed throughout the year and is highly reliable since it usually starts from the beginning of March with few exceptions like El-Nino or lamina where it comes earlier or later. The relative humidity which is the relationship between partial pressure of water vapour in the air-water mixture to the standard vapour pressure of water at a prescribed temperature mostly depends on temperature and the pressure of the system of interest. The average relative humidity of Kericho County is recorded at 83% from Tea Research Foundation (Currently, Tea Research Institute-TRI station of Kenya Meteorological department).

3.1.3 Soil status of the study region

The land pH at Ainamoi Location in Kericho-East Subcounty should be boosted annually with the use of farms / inorganic fertilizers, from high acids (4.78) to mildly alkaline (7.15) where the pH is lower than the most critical pH (5.0). The organic soil content in the sub-county varies from small (1.2% organic coal equivalent (OTOC) to sufficient (4.61% TOC). The suitable and later supplied in the soil are potassium and calcium. Where phosphorus, nitrogen and magnesium are small, fertilizers which derive these nutrients should be used to add the earth.

Table 3.1

Soil status of Ainamoi Location

Soil Parameter	**Min**	**Max**	**Target Level**	**Samples with below adequate**	**% of 60 below samples (30 – farms)**
pH	4.78	7.15	≥5.5	42 (<5.5)	70
Total organic Carbon (%)	1.20	4.61	≥ 2.7	13	22
Total nitrogen (%)	0.12	0.46	≥ 0.2	2	3
Available P (PPM)	7	229	≥ 30.0	54	90
Potassium (Me %)	0.30	2.24	≥ 0.24	0	0
Calcium (Me %)	2.3	11.9	≥ 2.0	0	0
Magnesium (Me %)	0.17	5.02	≥ 1.0	8	13

Manganese (Me %)	0.29	1.81	≥ 0.11	0	0
Copper PPM	0.02	2.83	≥ 1.0	55	92
Iron PPM	20.9	83.9	≥ 10.0	0	0
ZINC PPM	1.25	23.8	≥ 5.0	32	53

Source: MOA - Soil sustainability evaluation for maize production in Kenya (2014)

Non-acidic fertilizers are suggested for implementation in Kericho East Sub-County because the pH of groundwater is below 6.5 and the pH of crops is less than 5.5. Applications are suggested for fertilizers like three-phosphate (TSP), single superphosphate (SSP), and NPK 23:23:0, 20:20:0, 17:17:17, calcium ammonium nitrate, Mavuno, because zinc is also necessary as it is small in the bulk of soils. Soils were sampled on the fields and analysed for the purpose of evaluating accessible nutrients for manufacturing of finger millet at Tea Research Institute of Kenya (TRI) Laboratory in County of Kericho. The results of soil analysis are shown in table 3.2.

Table 3.2

Sampled Soils Results

Soil Depth (Cm)	pH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Mn (ppm)
30-35	5.37	39	1,120	735	196	65

3.2 Experimental Procedures

The plots were properly prepared to fine tilt using pangas, jembes, and raking to remove large soil clods and stones after the field was cleared of any bushes or tree stumps. Soil samples were taken for analysis to determine the position of available and adequacy of nutrients for plant performance. Field layout was done after demarcation and pegging out. Furrows were prepared to appropriate spacing, fertilizers at experimental rates were applied and seeds sown to the right depth and covered lightly. The experiment was carried out in a randomized complete block design (RCBD) replicated three times. The treatments were, three different spacing; 20, 30 and 40 cm, later thinned to 10 cm apart along the row, four treatments of DAP fertilizer (18:46:0) levels of 0, 75, 125 and 150 kg/ha and finger millet (P224 variety). After sowing, the research was carried out under rain-fed condition since rainfall was adequate throughout the growing season. Other management practices of top-dressing, chemical application for pest and disease control was done regularly depending on field scouting. Harvesting was done when the crop was mature at 4 months from planting time.

3.3 Treatments and Treatment Combinations

Four treatments of fertilizer levels of DAP (18:46:0); 0, 75, 125 and 150 kg/ha as main plot factor and three different spacing as follows, 20, 30 and 40 cm as sub-plot factors were applied.

Table 3.3

Treatment Combinations

FERTILIZER / SPACING		FT_1	FT_2	FT_3
S_1	**S_1FT_0**	**S_1FT_1**	**S_1FT_2**	**S_1FT_3**
S_2	**S_2FT_0**	**S_2FT_1**	**S_2FT_2**	**S_2FT_3**
S_3	**S_3FT_0**	**S_3FT_1**	**S_3FT_2**	**S_3FT_3**

Treatment Keys

S_1 – 40 x 10 cm FT_0 – 0 kg/ha

S_2 – 30 x 10 cm FT_1 – 75 kg/ha

S_3 – 20 x 10 cm FT_2 – 125 kg/ha

FT_3 – 150 kg/ha

3.4 Plot Layout

There were a total of 12 plots per block each of 3 x 3 m size which was laid on a randomized full block design with the spacing of 0.5 m between plots and spacing of 1m between blocks as follows:-

The figure below shows plots laid out in the field with each replicate spaced at 1 m distance.

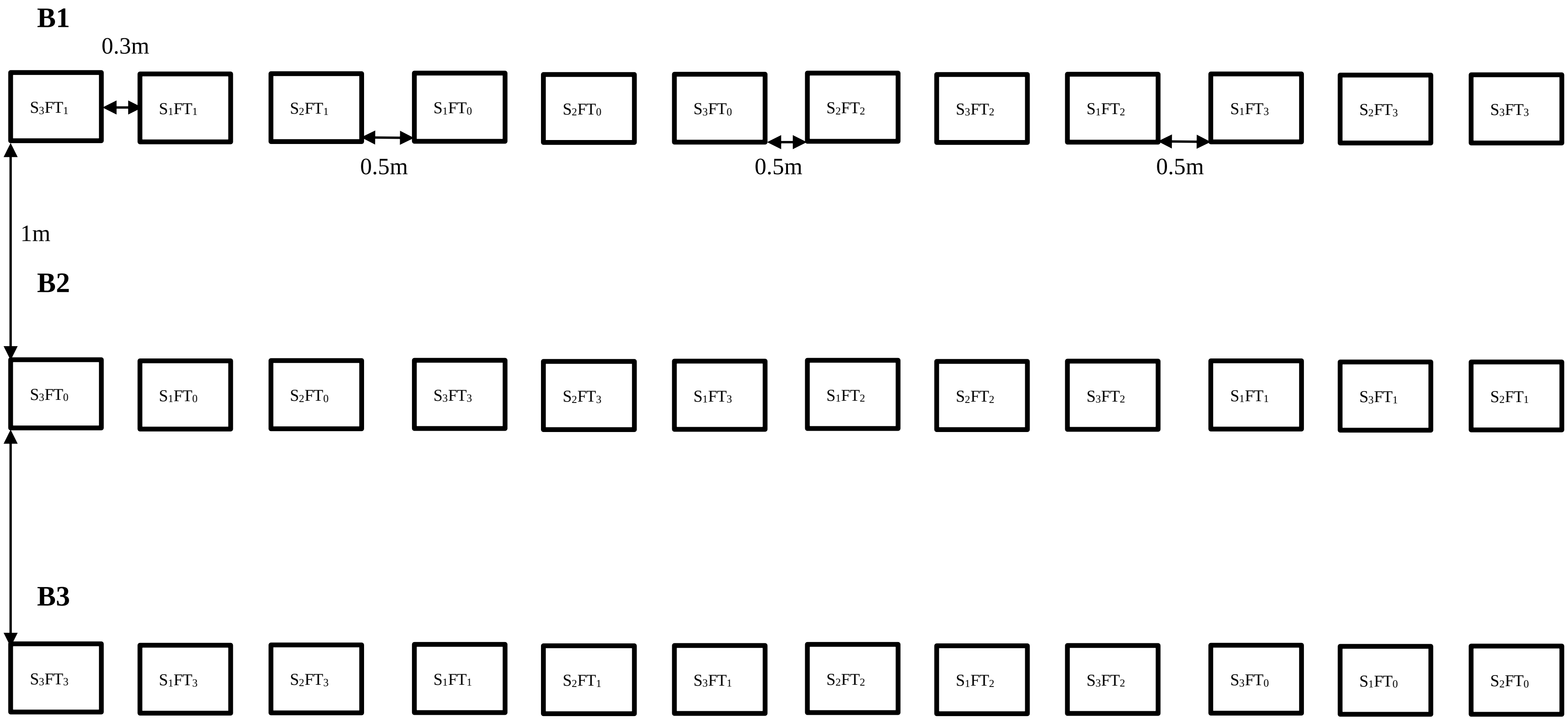

Figure 3.2 Plot Layout

The planting material used was one improved seed of finger millet variety P224 sourced from Kenya Seed Company Ltd. The other inputs were different levels of DAP fertilizer, top dressing fertilizer (CAN), pesticides and fungicides sourced from reputable and recommended agrochemical stores. Two weeks after germination, weeding was undertaken for the first time, followed by thinning to achieve the required plant population.

3.5 Data Collection

Data collection commenced two weeks from germination and continued till plant matured and harvested. Plant height and leaf length were measured with the use of a meter rule while the number of tillers and heads were counted physically from the five sampled plants in every plot. Measurements from the tagged five plants in the plant population were recorded from each plot throughout the experiment period and used for the analysis with the following parameters;

i. Plant height from two weeks after germination and at intervals of two weeks thereafter to maturity
ii. Length of the longest leaf/plant at intervals of two weeks after germination
iii. Number of tillers per plant after an initial thinning to the required plant population. The number of tillers was counted at intervals of two weeks
iv. Number of heads formed, counted at the time of harvest
v. Dry Biomass Weight after harvest
vi. Grain yield, measured at harvest using an electronic measuring scale

The process of measuring the grain yield was done using an electronic scale after harvesting from the field, drying and processing.

3.6 Data Analysis

The collected statistics are summarizing in Microsoft Excel and are submitted with the Statistical Social Sciences Package (SPSS) version 22 for Variance Analysis (ANOVA). The variance analysis was performed at a meaning level of 5 per cent. Where there were major variations between therapies, post-hoc trials were performed using an LSD ($p < 0.05$) to determine the recorded variations.

CHAPTER FOUR

RESULTS AND DISCUSSION

This section highlights the results of the study, analysis of results and the discussion of the findings based on the research objectives. The results of the research are recorded according to the objectives of the research, and the results obtained.

4.1 Plant Height

Data on plant height was taken from the five plants randomly selected from the plots and measured using a meter ruler from 14 days after germination followed by subsequent two weeks intervals until the plants mature at 105 days. As seen from Figure 4.1, the measurement was taken from ground level (base) up to the tip of the plant. Fertilizer application levels had an effect on plant height since with 0 kg/ha fertilizer application recorded a lower mean height compared to 150 kg/ha application while 75 kg/ha and 125 kg/ha application were in between.

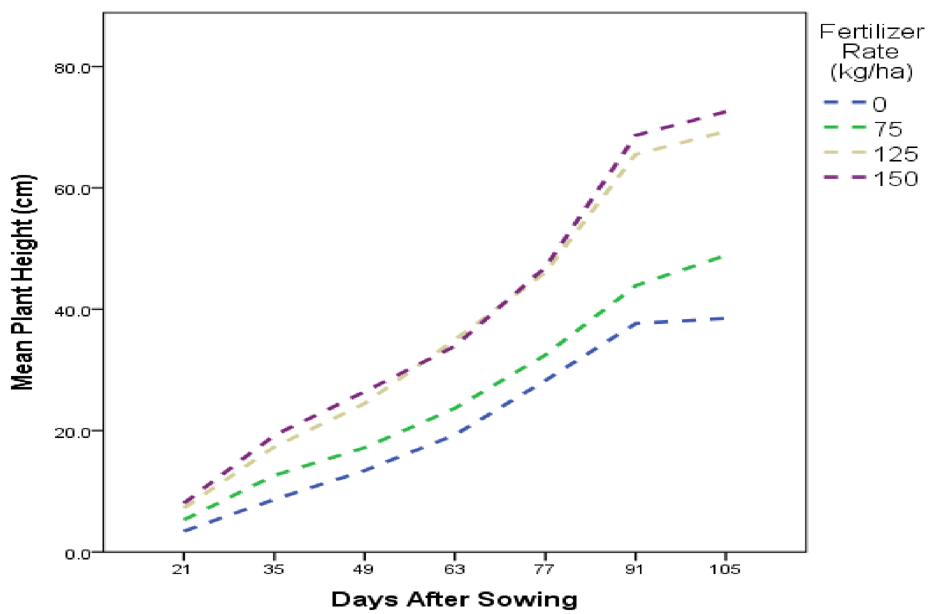

Figure 4.1 Mean changes in Plant Height

Table 4.1

ANOVA Table on Effects of Treatment on Plant Height

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Spacing	Plant Height (cm)	68.878	2	34.439	.085	.918
Fertilizer	Plant Height (cm)	12855.768	3	4285.256	10.599	.000
Spac * Fert	Plant Height (cm)	160.974	6	26.829	.066	.999
Error	Plant Height (cm)	97035.298	240	404.314		
Total	Plant Height (cm)	110120.919	251			

The results were further analyzed using ANOVA, and from the results in Table 4.1, the effect of spacing on plant height was not significant (P>0.005). Fertilizer effect was significant (P<0.005), while the interaction effect of spacing and fertilizer (P>0.005), at 0.999, as shown in table 4.1.

Table 4.2

Impacts of Fertilizer Rates on Plant Height

Fertilizer levels(kg/ha)	0	75	125	150
0		-3.423	-14.975*	-16.520*
75			-11.552*	-13.097*
125				-1.545
150				

*The mean difference is significant at the 0.05 level

Analysis to establish variation in plant height due to treatments indicated that there were significant influences ($P<0.05$) on crop height arising from the application of DAP fertilizer at different levels, there was no significant ($P>0.05$) variation in plant height because of the differences in spacing as shown in table 4.3.

From the results, it shows that the application of fertilizers had a positive significant effect ($P< 0.05$) on the plant height (Fig. 4.1 and Table 4.2). There was no remarkable difference in mean plant height between 0 and 75 kg DAP/ha fertilizer application. A mean difference in plant height of about 15.9 cm was observed connecting no fertilizer application and 125 kg DAP/ha and with the difference of 5% alpha level.

The difference in mean plant height between no fertilizer (0kg/ha) and 150 kg DAP/ha was significantly different with a mean difference of about 16.5 cm. A comparison between 75 kg DAP/ha and 125 kg DAP/ha gave a mean difference of about 11.5 cm and the difference was significant at 5% alpha level. 75 kg DAP/ha and 150 kg DAP/ha similarly gave a significantly different mean plant height of about 13.1 cm.

There was however no significant difference between 125 kg DAP/ha and 150 kg DAP/ha. Plant height seemed to increase with an increase in fertilizer level but, no fertilizer gave a lower mean plant height compared to 125 and 150 kg DAP/ha respectively. Also, 125 kg DAP/ha gave a higher mean plant height compared to 75 kg DAP/ha while 125 and 150 kg DAP/ha did not depict a noteworthy consideration (Table 4.2).

These results suggest that fertilizer rates influenced plant height with varied results with fertilizer levels but beyond 125 kg DAP/ha application no influence is noticeable in changes in plant height.

The same results have been reported by Haraldsen, Pedersen and Grønlund, (2011) in an experiment conducted in India, where the authors observed that growth factors like plant height differed significantly with the direct influence of fertilizer application levels which they attributed to the difference to the major roles played by N & P in plant growth. Current observations show that N & P in DAP fertilizer applied may have been responsible for the differences in plant growth may have been because of the position of Nitrogen in the synthesis of proteins and other growth factors and Phosphorus in root development which encourages nutrient uptake as noted by Wafula et al. (2016) in an experiment done in two sites in Western Kenya (Alupe & Kakamega) where the authors reported that increased levels of Phosphorus increased the grain yields over non fertilizer application during the long and short season in both sites.

4.2 Leaf Length

The length of the longest leaf from the five randomly selected plants in each plot was studied from the extremity of attachment to the stem up to the tip of the leaf using a meter rule. The measurements were taken two weeks after germination and on two weeks intervals thereafter until when the crop gained physiological maturity i.e. when the leaves stagnated in growth at 105 days after sowing and the results are given in Figure 4.2. The higher fertilizer dose of 150 kg/ha registered the longest leaf length recorded compared to 0 kg/ha application rate and the results can be seen in the other of applications of 75 and 125 kg/ha respectively as it can be observed from Figure 4.2.

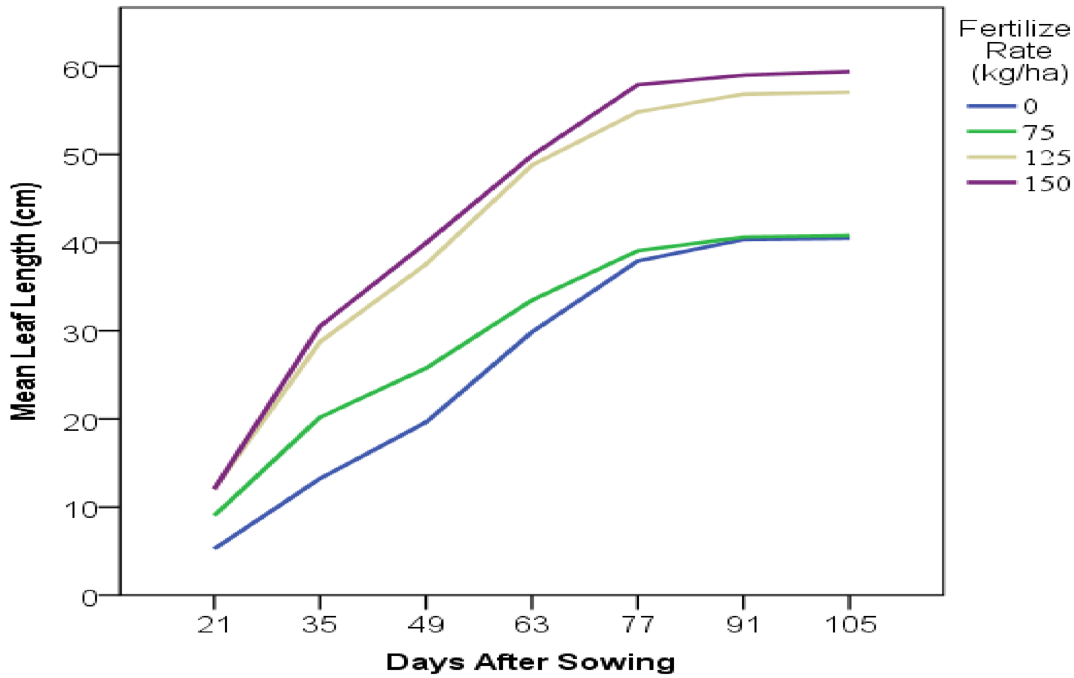

Figure 4.2 Leaf Length Response to Different Fertilizer Rates

Table 4.3.

ANOVA on Leaf Length

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Spacing	Leaf Length (cm)	272.379	2	136.190	.588	.556
Fertilizer	Leaf Length (cm)	14442.596	3	4814.199	20.783	.000
Spac * Fert	Leaf Length (cm)	114.499	6	19.083	.082	.998
Error	Leaf Length (cm)	55593.890	240	231.641		
Total	Leaf Length (cm)	70423.364	251			

After subjecting the results to ANOVA, the spacing had no remarkable difference in leaf length an as shown in table 4.3 (P>0.05). Whereas, fertilizer effect had a remarkable impact on leaf length, (P<0.05). As shown in table 4.3 and 4.4, the relationship effect of spacing and fertilizer was not significant (P>0.05),

Table 4.4.

Impact of Fertilizer Rates on Leaf Length

Fertilizer levels(kg/ha)	0	75	125	150
0		-3.169	-15.589*	-17.417*
75			-12.420*	-14.248*
125				-1.828
150				

Mean Separation by LSD (* significant at 5% level of significance)

When the data on leaf lengths were subjected to the examination of variance, it showed a remarkable difference (P< 0.05) due to the application of fertilizer; however, the differences due to spacing were not significant at the 5% level of significance (Appendix I). The observations made indicates that at doses above 75 kg/ha, the fertilizer enhanced vegetative growth, but there was no added growth change when the dose exceeded 125 kg/ha as there was no significant difference in plant height between the 125 kg/ha plots and the 150 kg/ha plots. There was no significant difference in mean leaf length between 0 fertilizer application and 75 kg DAP/ha. There was a mean difference in leaf length of about 15.6 cm between no fertilizer application and 125 kg DAP/ha and the difference was significant at 5% alpha level.

Similarly, the difference in mean leaf length between no fertilizer and 150 kg DAP/ha was significantly different with a mean difference in leaf length of about 17.4 cm. A comparison between 75 kg DAP/ha and 125 kg DAP/ha gave a mean difference of about 12.42 cm and the difference was significant at 5% alpha level. 75 kg DAP/ha and 150 kg DAP/ha also gave a significantly different mean leaf length of about 14.2 cm. However, there was no significant difference between 125 kg DAP/ha and 125 kg DAP/ha (Table 4.4). The leaf length appeared to increase with increasing levels of fertilizer; with no fertilizer giving a lower mean leaf length compared to 125 kg DAP/ha and compared to 150 kg DAP/ha.

Similarly, 125 kg DAP/ha gave higher mean leaf length compared to 75 kg DAP/ha while 125 kg DAP/ha and 150 kg DAP/ha did not differ significantly (Table 4.4). These results seem to suggest that the leaf length is influenced by fertilizer levels as indicated by 0 fertilizer level giving lower leaf length compared with 75 or 125 kg DAP/ha. Similar results have been reported by Pradhan, Thakur, Patel and Mishra (2011) from an experiment conducted in India Department of Agronomy, where the authors observed that leaf length varied significantly as influenced by different fertilizer levels. The authors attributed the differences to the critical role played by Nitrogen and Phosphorus in the process of photosynthesis and assimilation of photosynthesis. From current observations, it is suggested that P in the DAP fertilizer applied may have been directly responsible for the differences in leaf elongation probably due to the role of Nitrogen in the synthesis of proteins and other organic substances in the plant and the role of phosphorus in root development which enhances nutrient uptake. These two synergistic nutrients apparently may have contributed to the differences in leaf growth. The uptake of nutrients and water is mostly a function of root development as asserted by Pradhan et al., (2011).

4.3 Number of Tiller

Data on the number of tillers was taken from the randomly selected five plants per plot was counted manually and recorded. Means were computed and subjected to analysis of variance. Analysis of variance indicated a significant difference at ($P<0.05$) was due to the differences in spacing (plant population). There were also significant differences ($P < 0.05$) due to the application of fertilizer.

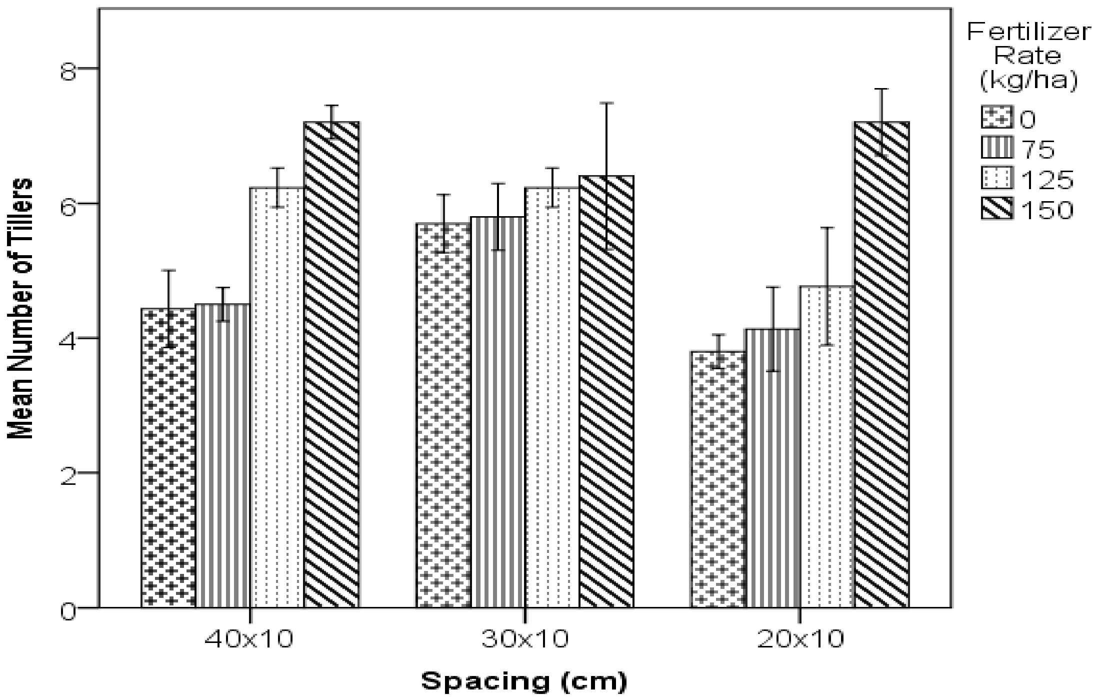

Figure 4.3 Effects of Treatments on Number of Tillers per Plant

From figure 4.3, it can be observed that the wider spacing and higher fertilizer application rate recorded the highest number of tillers. Data on the number of tillers was taken from the randomly selected five plants per plot was counted manually and recorded. Means were computed and subjected to analysis of variance. Analysis of variance indicated that the significant difference ($P<0.05$) was due to the differences in spacing (plant population)

(Figure 4.3). There were also significant differences (P < 0.05) due to the application levels of fertilizer.

Table 4.5.

ANOVA on Number of Tillers

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	Number of Tillers	.961	2	.480	.256	.776
Fertilizer	Number of Tillers	35.034	3	11.678	6.224	.003
Spacing	Number of Tillers	4.554	2	2.277	1.214	.316
Spac *Fert	Number of Tillers	6.068	6	1.011	.539	.773
Error	Number of Tillers	41.279	23	1.876		
Total	Number of Tillers	1184.610	36			

*Significant at 0.05 level

After the data were subjected to ANOVA, the results indicated that fertilizer application showed a significant difference in the number of tillers (P<0.05), while spacing had no significant difference (P >0.05). The interaction effect of fertilizer had a significant difference with the number of tillers formed, while spacing did not have a significant difference.

Tiller formation was significantly influenced by the application of DAP (Table 4.5) and there were significant differences among all the fertilizer levels, the control (no fertilizer) had a lower number of tillers than all the levels of fertilizers (Figure 4.3). This indicates that fertilization encouraged tiller formation in the crop. The two wider spatial arrangements of 30 x 10 cm and 40 x 10 cm appeared to encourage tiller formation.

Table 4.6.

Effect of Fertilizer Rate on Number of Tillers

Fertilizer levels(kg/ha)	0	75	125	150
0		.009	.004*	.003*
75			.003*	.001*
125				.000*
150				

Means separated by LSD at 0.05, * Significant at .05 level

From the results, it shows that there was no significant difference in the mean number of tillers between the spacing of 20 x10 cm and 30 x 10 cm of about 0.5. Also, there was no significant difference in the mean number of tillers between 20 x 10 cm and 40 x 10 cm of about 0.3 but, there was no significant difference in the mean number of tillers between 30 x 10 cm and 40 x 10 cm, indicating that tiller formation is encouraged by a wider spacing. This results did not agree with the results reported by Makete, Gohole, Opile and Oduori (2017) who carried out an experiment conducted in Kisii highlands, southwest Kenya (KARI) as a high potential conditions areas showed that finger millet spacing is a key factor in tiller formation which influences grain yields. Furthermore, a study carried out by Adeyemo and Agele (2010), who reported that the treatment of tillers using fertilizer enhanced nutrient efficiency as well as soil quality and health.

4.4 Number of Heads

The data on the number of heads per plant from the five randomly sampled plants from each plot were taken and recorded at 105 days after sowing. The number of heads per plant was taken by physically counting then the data recorded was analyzed using SPSS to generate the figures.

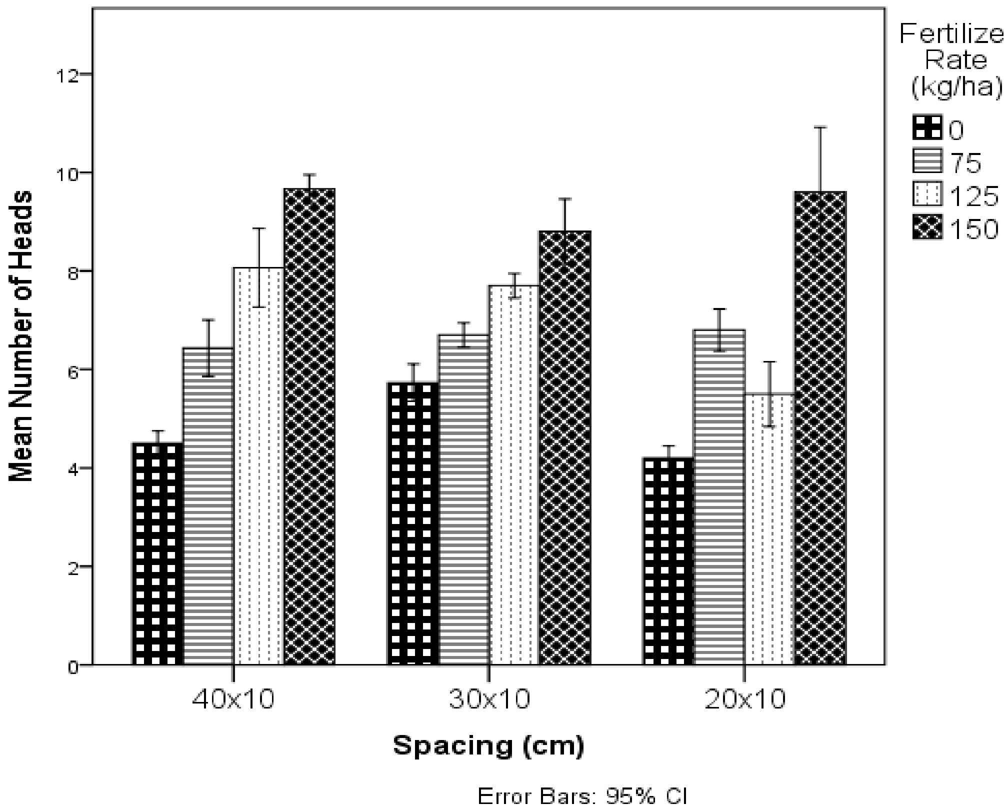

Figure 4.4 Effects of Spacing and Fertilizer Level on Number of Heads

It can be seen from figure 4.4 that the effect of fertilizer and the number of heads was not noticeable since the wider spacing and higher fertilizer application rate recorded the highest number of heads formed per plant. Furthermore, from the ANOVA table 4.10, it can be deduced that spacing had no significant difference in the number of heads formed (P>0.05), but fertilizer effect showed a significant difference (P <0.05). Also, the interaction effect of fertilizer and spacing was not significant (P>0.05) as shown in table 4.7.

Table 4.7.

ANOVA on Number of Heads

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	Number of Heads	3.654	2	1.827	.283	.756
Fertilizer	Number of Heads	116.190	3	38.730	5.995	.004
Spacing	Number of Heads	6.217	2	3.109	.481	.624
Spac *Fert	Number of Heads	11.665	6	1.944	.301	.930
Error	Number of Heads	142.133	23	6.461		
Total	Number of Heads	1850.660	36			

*Significant at 0.05 level

The number of heads counted from the sampled plants at physiological maturity for each treatment was subjected to analysis and results indicated a significant influence of fertilizer application on the number of heads per plant. Plots also differed significantly (P<0.05) on the number of heads per plant due to variation in spacing (Figure 4.4). The results demonstrated that there wasn't a significant difference between the spatial arrangement of 30x10 cm and 40x10 cm in the mean number of heads formed at the maturity of the plants.

The difference in the mean number of heads was shown between 20 x 10 cm and 30x10 cm with a mean number of heads of about 0.7 whereas there was also a significant difference I mean the number of heads formed between the spacing of 20 x 10 cm and 40 x 10 cm with a difference of about 0.6.

Table 4.8.

Effect of Fertilizer rate on Number of Heads

Fertilizer levels(kg/ha)	0	75	125	150
0		.009	.009	.007
75			.082*	.005
125				.004*
150				

This is in conformity with what was reported by Makete, Gohole, Opile and Oduori (2017) in an experiment conducted in KARI, Kisii, where it was reported that optimum finger millet yields is possibly obtained with a spacing of 30 x 10 cm with a population of 333,333 plants produced more grains per ha compared to a wider spacing of 40x10 cm or a narrow spacing of 20x10 cm which was in conformity with the results reported in an experiment conducted in Kakamega in western Kenya (Mgonja et al., 2013).

4.5 Biomass

The entire plant parts from the sampled plants were completely dried to constant weight, then weighed and their weights recorded according to treatments. This ensured that the researcher could obtain accurate data on the dry biomass weight to enable a conclusive set of data.

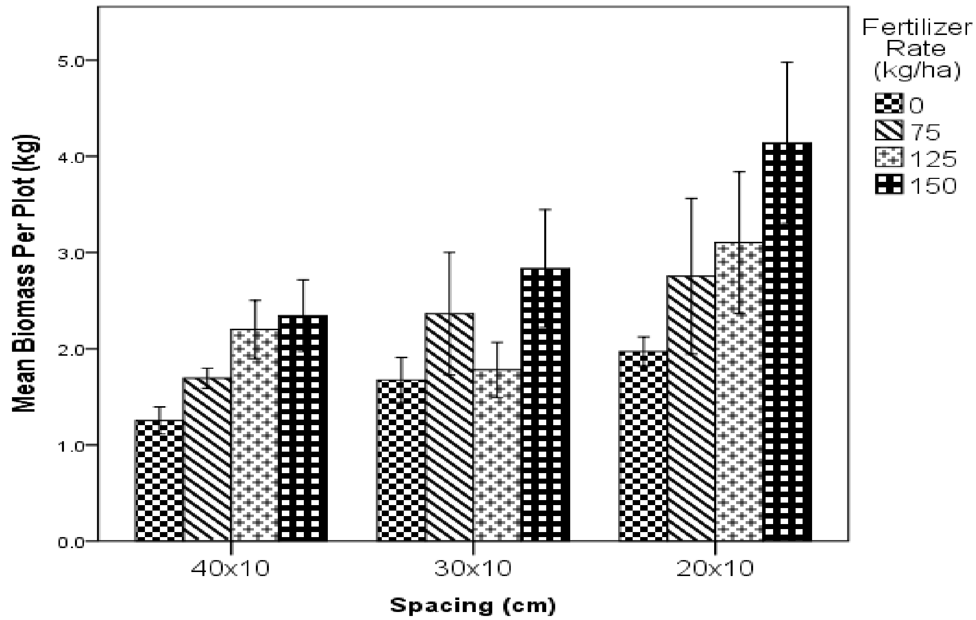

Figure 4.5. **Effect of Spacing and Fertilizer on Biomass**

The entire plant parts from the sampled plants were completely dried to constant weight, then weighed and their weights recorded according to treatments. Figure 4.5 shows that fertilizer and spacing a significant effect on the biomass of finger millet crop with wider spacing of 40 x 10 cm recording the lowest biomass compared with closer spacing of 20 x 10 cm.

Table 4.9.

ANOVA Table on Biomass

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
BK	.220	2	.110	.162	.852
Fertilizer	10.218	3	3.406	5.000	.009
Spacing	9.124	2	4.562	6.697	.005
Spac *Fert	2.182	6	.364	.534	.777
Error	14.986	23	.681		
Total	227.354	36			

*Significant at 0.05 level

From the ANOVA results showed in table 4.9, it can be seen that fertilizer had significant difference in dry biomass ($P<0.05$), while spacing had a significant difference ($P<0.05$). The interaction effect of fertilizer and spacing had A significant difference in biomass ($P<0.05$).

Table 4.10.

Spacing Effects on Plant Biomass

Spacing(cm)	20x10	30x10	40x10
20x10		.009	.777
30x10			.005*
40x10			

Table 4.11.

Fertilizer Effects on Plant Biomass

DAP/ha	0	75	125	150
0		-0.638*	-0.729*	-1.473*
75			-0.091	-0.836*
125				-0.744*
150				

Means were separated by LSD at 0.05 α level, * Significant at 0.05 level

The data subjected to analysis indicated a significant difference in the quantity of dry biomass generated per plot as a result of differences in fertilizer levels and spacing (Table 4.9). Closer spacing of 20 x 10 cm gave significantly higher biomass compared to a wider spacing of 30 x 10 cm and 40 x 10 cm. The higher plant population gave rise to more plant material. The control plot; without added fertilizer gave significantly lower biomass compared to the plots with fertilizer (Table 4.11). From the results, a comparison of no fertilizer application and 75 kg DAP/ha had a significant difference in biomass of about 0.6. No fertilizer application and 125 kg DAP/ha showed some significant difference of about 0.7, whereas no fertilizer and 150 kg DAP/ha had a significant difference of approximately 1.4. Fertilizer application of 75 kg DAP/ha compared with 125 kg DAP/ha had no significant difference while a comparison between 75 and 150 kg DAP/ha had a significant difference of about 0.8.

A comparison of 125 and 150 kg DAP/ha had a significant difference of 0.7. The Nitrogen and Phosphorous nutrients in the DAP (18:46:0) fertilizer may have encouraged plant growth through its supply of Nitrogen for vegetative growth and phosphorous for root development and subsequently improved uptake of other nutrients from the soil as reported by (Wafula et al., 2016).

4.6 Grain Yield

There were significant differences at ($P<0.05$) between the plots on grain yield due to the differences in fertilizer levels and differences in plant population (spacing) as illustrated in (Figure 4.6). Grain yield from the control (no fertilizer) was significantly lower, the highest application of 150 kg DAP/ha gave the highest mean grain yield (Figure 4.6).

After subjecting the results to an ANOVA test as shown in table 4.16, it was observed that fertilizer application and spacing had a significant difference in the grain yield, with a P-value of 0.004, and 0.002 respectively. Furthermore, the interaction effect of fertilizer and spacing did not show any significant difference ($P>0.05$) as captured in table 4.13.

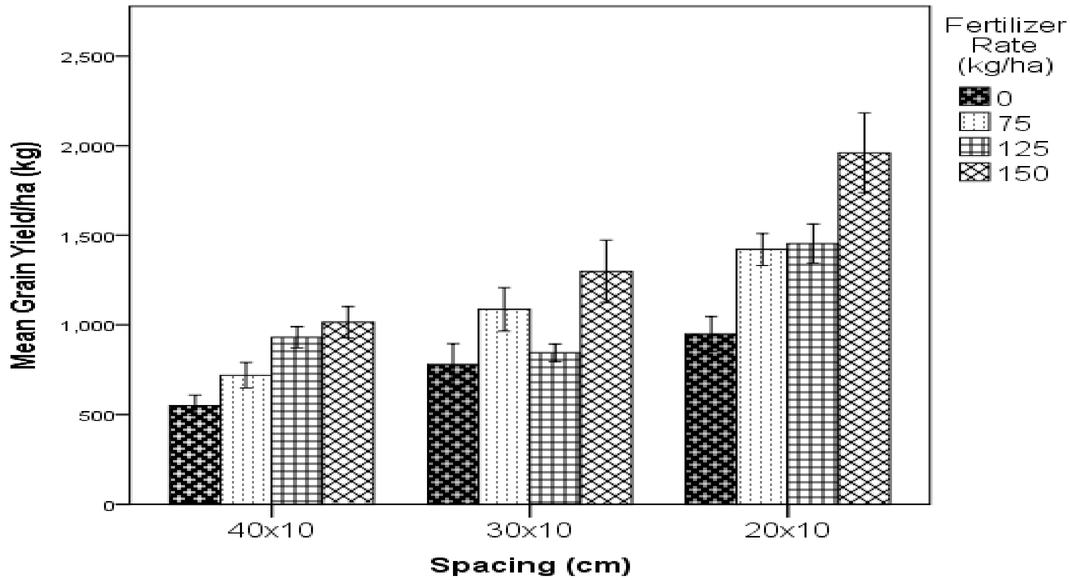

Figure 4.6 **Effect of Spacing and Fertilizer Level on Grain Yield**

Table 4.12.

ANOVA on Grain Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
BK	41694.255	2	20847.127	.162	.852
Fertilizer	2249831.667	3	749943.889	5.815	.004
Spacing	2082213.202	2	1041106.601	8.072	.002
Spac* Fert	426240.578	6	71040.096	.551	.764
Error	2837496.118	23	128977.096		
Total	49190970.260	36			

Table 4.13.

Spacing Effects on Grain Yield

Spacing(cm)	20x10	30x10	40x10

20x10		.900*	.005
30x10			.002
40x10			

Table 4.14.

Fertilizer Effects on Grain Yield

DAP/ha	0	75	125	150
0		-315.78*	-316.89*	-664.78*
75			-1.1	-349.00*
125				-347.89*
150				

Means separated by LSD at 0.05 α level, * Significant at 0.05 level

There was a significant increase in grain yield as the fertilizer levels increased; 75 kg/ha of fertilizer gave a significantly higher mean yield when compared with the control which had a mean yield difference of about 315 kg/ha, similarly the 125 kg/ha fertilizer gave a significant mean yield increase of about 316 kg/ha from the control as indicated in table 4.14. The higher fertilizer dose of 150 kg/ha gave the highest grain yields; a mean difference of about 664, 349 and 347 kg with the control, 75 kg/ha and 125 kg/ha respectively (Table 4.14). This finding suggests that Finger millet grain yield was responsive to fertilizer application.

Fayisa, Welbira and Bekele (2016) reported similar findings for N levels (23, 46, 69 & 92 kg of N/ha) in grain yields in experiments conducted in Gumuz region of Ethiopia. The researchers found that increasing the levels of P led to increased grain yield and increasing N levels from 0 to 92 kg/ha gave a significantly higher grain yield of finger millet raising the yield from 1142 to 1769 kg/ha. The presence of Nitrogen and Phosphorous in the test fertilizer may have supplied N and P nutrients required for increased photosynthetic activity and accumulation of organic matter in the crop resulting in higher grain yields. Haruna and Aliyu (2011) have also pointed out the importance of phosphorous in grain formation in cereals.

Table 4.15.

Effects of Spacing on Mean Grain Yield (Kg/Ha)

Spacing(cm)	20x10	30x10	40x10
20x10		443.50*	641.83*
30x10			198.33*
40x10			

Means separated by LSD at 0.05 α level, * Significant at 0.05 level.

The closer spacing of 20x10 cm gave a significantly higher grain yield compared to the wider spacing of 30x10 cm and 40x10 cm (Table 4.19). This may have been mainly attributed to the higher plant population that resulted in a higher number of heads and more grains from the closer spacing compared to the wider spacing. The adverse effect of competition between plants associated with closer spacing may not have been significant as to affect yields at a spacing of 20x10cm. Shinggu et al. (2009) reported similar results in which a narrow spacing had a strong positive effect on crop biomass and yield. They further state that the narrow spacing suppresses weeds and eventually leads to increased yields.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The purpose behind this study was to access the effect of fertilizer levels and spacing of plant population on growth and yields of finger millet (*Eleusine coracana* L.) in Ainamoi, Kericho County. Summary of the findings in the study is presented in this chapter. The conclusions on the results obtained from the study. The recommendations and the areas for further research are also outlined.

5.1 Conclusion

The distance levels tested did not affect leaf length and plant height significantly. Differentiation and therefore the formation of the tillers with a nearer distance of 20x 10 cm show a remarkable smaller tillering in relation to a larger distance of 30x 10 cm and 40x 10 cm, was affected considerably and subsequently. It is therefore found that a greater distance of 20x 10 cm is beneficial to tillering and a wider range. The interplant rivalry for nutrients and the rivalry for synthetically effective radiation may be ascribed to this. However, as compared to the wider spacings of 30x10 cm and 40x10 cm, the number of heads per plant was higher due to its larger population at a narrower distance of 20x10 cm. As a result, the yield for closer distance was considerably higher compared to 30 x 10 cm and 40 x 10 cm.

It is concluded that the higher number of heads associated with the closer distance was not adequately compensated by this, and a close distance of 20x10 cm, therefore, outweighed the width of 30x10 cm and 40x10 cm and considerably increased the yields of grain, even if a broader range of head and plant elongation promotes development and tiller development. Inorganic fertilizer DAP application (18:46:0) was significant in crop growing, according to the height and length of its plant.

Increased growth in height and in length with respect to no fertilizer and the lower doses of 75 kg DAP/ha was shown by the increased 125 and 150 kg DAP/ha rates. The impact of fertilization in tiller creation was quite important; the number of tillers/plant in non-fertilizer therapy was considerably smaller. The higher fertilizer dose provided the highest biomass and grain yield. In addition, the greater dose (150 kg/ha) resulted in increased development and efficiency in grain output. Finger millet P224 reacted in a number of development and output factors to DAP. The interaction between spacing and fertilizers use on growth and yield variables was ineffective for finger millet variety P224.

5.2 Recommendations

With a deeper spacing of 20x 10 cm, the number of heads per unit region for the P224 finger millet type was increased, and general grain production was increased. Consequently, in the field of research for greater crop yield, the suggestion is to recommend producers that they take a deeper distance for Finger millet species P224.

Inorganic fertilizer DAP has been improved at rates above 125 kg DAP / ha, improving the development and output characteristics of the plant. A farmer was suggested that DAP/ha should be at least 125 kg/ha. In order to set the suitable level of use for N and P fertilizers, however, particular soil studies are suggested. In addition, the study on right plant communities is suggested for optimal output since the present three concentrations have been deficient to determine the precise concentrations of plants desired for the P224 type.

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APPENDICES

APPENDIX I: RAINFALL FIGURES FOR AINAMOI (2005 TO 2015)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total Amt(mm)
2005	70	0	50	220	310	260	80	112	182	224	280	334	2113
2006	45	20	72	112	160	90	40	150	105	62	30	126	1012
2007	100	90	60	45	110	70	301	220	142	55	270	190	1653
2008	70	160	132	90	215	80	0	50	200	74	120	300	1491
2009	125	195	264	115	300	130	100	280	135	110	86	118	1958
2010	50	320	112	193	48	95	76	74	100	290	38	250	1646
2011	115	230	40	260	50	170	0	90	182	224	0	100	1461
2012	35	75	100	304	200	235	212	88	90	112	95	205	1751
2013	50	80	290	116	65	301	58	40	66	301	110	60	1537
2014	120	90	100	45	210	212	37	117	60	260	75	40	1266
2015	60	115	130	305	35	224	0	90	65	112	82	110	1328

Source: KTDA, Toror Tea Factory

APPENDIX II: SOIL SAMPLES ANALYSIS RESULT

ALL COMMUNICATIONS SHOULD BE ADDRESSED TO THE DIRECTOR

KALRO
Kenya Agriculture & Livestock Research Organization

P.O. Box 820-20200, Kericho, Kenya
Telephone: Kericho +254-052-20598/9, 0722-209915, 0735-337813
Fax:+254-052-20575
E-mail: info@tearesearch.or.ke
Website: www.tearresearch.or.ke

TEA RESEARCH INSTITUTE

TRI/TECH/18

Please Quote Ref.:

3rd May, 2016

Mr. Andrew K. Korir,
P.O. Box 880,
KERICHO.

Dear Sir,

RE: SOIL SAMPLES

Below are analytical results for your soil analysis request of 18th April, 2016.

Site	Plot/Field	Soil depth (Cm)	pH	P ppm	K ppm	Ca ppm	Mg ppm	Mn ppm
Andrew Korir		30-35	5.37	39	1120	735	196	65

Yours faithfully,

Mr. Karl Nyabundi
Programme Leader SEMC
For: INSTITUTE DIRECTOR

Tea Research Institute is ISO 9001:2008 Certified

APPENDIX III: RAW DATA

Plant Growth Data

Block	Fert Level	Spacin g	DAS	Heigh t (cm)	Leaf Length (cm)
1	1	3	21	5.4	10.6
1	1	1	21	5.6	10.3
1	1	2	21	6.1	10.3
1	0	1	21	3.9	5.9
1	0	2	21	4.5	6.7
1	0	3	21	4.1	6.8
1	2	2	21	7.8	13
1	2	3	21	7	12.2
1	2	1	21	5.5	12.9
1	3	1	21	9	14.2
1	3	2	21	9.4	11.5
1	3	3	21	8.3	12.6
2	0	3	21	3.1	4.2
2	0	1	21	2.9	5.6
2	0	2	21	3.2	4.5
2	3	3	21	5.9	11.8
2	3	2	21	5.6	8
2	3	1	21	8	12.7
2	2	1	21	5.4	10.5
2	2	2	21	7.8	12.2

Block	Fertilize r Level	Spacing	DAS	Heigh t (cm)	Leaf Length (cm)
2	0	3	49	10.5	17.8
2	0	1	49	17.2	26.3
2	0	2	49	17.6	22.1
2	3	3	49	23.2	34.8
2	3	2	49	25.4	37.8
2	3	1	49	33.5	48.7
2	2	1	49	23.1	38.9
2	2	2	49	28.8	40.7
2	2	3	49	24.5	40.8
2	1	1	49	17.8	31
2	1	3	49	16.1	22.5
2	1	2	49	18.5	29.4
3	3	3	49	26.6	38.6
3	3	1	49	25.9	45.5
3	3	2	49	31.7	46.6
3	1	1	49	20.5	30.1
3	1	2	49	22.4	32.4
3	1	3	49	17.1	27.3
3	2	2	49	25.7	37.8
3	2	1	49	27.5	44.2

Block	Fertilize r Level	Spacing	DAS	Heigh t (cm)	Leaf Length (cm)
3	3	3	77	49.3	58.3
3	3	1	77	49.2	61.4
3	3	2	77	50.4	62.4
3	1	1	77	45	47.4
3	1	2	77	43.9	43.7
3	1	3	77	40.7	44.6
3	2	2	77	49.3	55.9
3	2	1	77	50.7	58.1
3	2	3	77	50.7	56.8
3	0	3	77	30.2	36.9
3	0	1	77	29.3	40.5
3	0	2	77	33.5	39.4
1	1	3	91	24.1	25.9
1	1	1	91	32.8	30.3
1	1	2	91	40.7	35.8
1	0	1	91	31.1	33.4
1	0	2	91	31.1	36
1	0	3	91	31.7	36.5
1	2	2	91	61.4	53.5
1	2	3	91	60.1	54.3

2	2	3	21	8.7	12.4
2	1	1	21	5.2	9.7
2	1	3	21	4.9	7
2	1	2	21	4.1	7.1
3	3	3	21	8.5	11.5
3	3	1	21	8.3	13.3
3	3	2	21	9.5	12.6
3	1	1	21	4.2	8.7
3	1	2	21	6.8	9.4
3	1	3	21	5.5	8.1
3	2	2	21	7.3	10.5
3	2	1	21	8.1	13.5
3	2	3	21	7.9	11.4
3	0	3	21	3.1	5.1
3	0	1	21	3.3	4.5
3	0	2	21	3.2	4
1	1	3	35	10.4	14.9
1	1	1	35	12.3	16.5
1	1	2	35	10.6	16.8
1	0	1	35	8.1	10.6
1	0	2	35	7.4	11.2
1	0	3	35	9.4	13.6
1	2	2	35	14.9	21.9
1	2	3	35	14.2	20
1	2	1	35	16.9	30.8
1	3	1	35	17	22.8
1	3	2	35	19.2	28.8
1	3	3	35	16.9	28.2
2	0	3	35	8.5	12

3	2	3	49	23.1	32.9
3	0	3	49	13.6	17.1
3	0	1	49	14	21.4
3	0	2	49	12.4	18.9
1	1	3	63	16.2	21.9
1	1	1	63	18.6	25.3
1	1	2	63	18.6	28.5
1	0	1	63	15.8	23
1	0	2	63	19.2	27.5
1	0	3	63	18.5	30.8
1	2	2	63	28.5	43.5
1	2	3	63	33.9	45
1	2	1	63	37.5	50.4
1	3	1	63	31.3	44.8
1	3	2	63	32.4	49.1
1	3	3	63	34.1	47.2
2	0	3	63	19.4	30.8
2	0	1	63	22.7	36
2	0	2	63	21	34.6
2	3	3	63	28.2	46.3
2	3	2	63	31.8	52.4
2	3	1	63	37.4	54
2	2	1	63	30.6	47.5
2	2	2	63	35.6	52.1
2	2	3	63	36.1	48.4
2	1	1	63	23.4	37.4
2	1	3	63	21.2	30.8
2	1	2	63	24.9	35.6
3	3	3	63	37.2	50.6

1	2	1	91	64.7	57.9
1	3	1	91	69.4	58.1
1	3	2	91	60.5	56.2
1	3	3	91	68.2	54.7
2	0	3	91	40.9	42.8
2	0	1	91	38.5	44.5
2	0	2	91	44.3	45
2	3	3	91	63.8	56.2
2	3	2	91	70.6	59.3
2	3	1	91	75.4	61.4
2	2	1	91	58.3	56.5
2	2	2	91	68.4	57.9
2	2	3	91	68.6	57.9
2	1	1	91	44.3	44.5
2	1	3	91	43.4	42.1
2	1	2	91	49.3	45.5
3	3	3	91	68.4	60.5
3	3	1	91	65.3	61.9
3	3	2	91	76.6	62.6
3	1	1	91	51.7	49.1
3	1	2	91	54.9	47.3
3	1	3	91	54.2	44.8
3	2	2	91	65.6	56.7
3	2	1	91	69.7	59
3	2	3	91	73.3	57.9
3	0	3	91	41.4	40.9
3	0	1	91	40.5	42.5
3	0	2	91	39.6	41.6
1	1	3	105	26.5	26.6

2	0	1	35	11.3	18.5
2	0	2	35	9.4	16.1
2	3	3	35	16.6	26.3
2	3	2	35	19.3	29.6
2	3	1	35	23.5	37.7
2	2	1	35	15.2	25.7
2	2	2	35	20	32.5
2	2	3	35	19.4	34.7
2	1	1	35	14.7	23.9
2	1	3	35	11.4	18.6
2	1	2	35	12.6	24.3
3	3	3	35	19.4	30.2
3	3	1	35	19.9	33.5
3	3	2	35	21.2	37.4
3	1	1	35	14.1	21.8
3	1	2	35	15.3	23.2
3	1	3	35	12.3	21.6
3	2	2	35	17.8	29.2
3	2	1	35	19.8	35.4
3	2	3	35	17.9	28.6
3	0	3	35	7.7	11.9
3	0	1	35	7.3	12.6
3	0	2	35	9.2	12.7
1	1	3	49	14	18.2
1	1	1	49	14.2	19.9
1	1	2	49	14	21
1	0	1	49	11.2	14.6
1	0	2	49	12.2	19.8
1	0	3	49	12.2	18.5

3	3	1	63	34.7	50.9
3	3	2	63	38.4	53.4
3	1	1	63	31.1	42.4
3	1	2	63	31.8	41
3	1	3	63	27.6	38.2
3	2	2	63	35.2	49.5
3	2	1	63	40.6	54
3	2	3	63	37	48.5
3	0	3	63	18.8	25.6
3	0	1	63	20.3	31.4
3	0	2	63	18.4	28.9
1	1	3	77	19.4	25.7
1	1	1	77	22.1	29.3
1	1	2	77	25.5	34.1
1	0	1	77	22.3	30.7
1	0	2	77	23.6	34.7
1	0	3	77	25.4	36.5
1	2	2	77	36.7	49.3
1	2	3	77	45	52.6
1	2	1	77	42.8	52.8
1	3	1	77	48.5	55.9
1	3	2	77	44.2	54.5
1	3	3	77	43.9	53.9
2	0	3	77	27.8	37.1
2	0	1	77	28.3	42.3
2	0	2	77	34	43
2	3	3	77	38.9	55.3
2	3	2	77	50.2	58.6
2	3	1	77	48	60.7

1	1	1	105	39.4	30.4
1	1	2	105	43.2	35.9
1	0	1	105	32	33.6
1	0	2	105	31.7	36
1	0	3	105	31	36.7
1	2	2	105	61.4	53.7
1	2	3	105	60.9	55
1	2	1	105	64.7	58.1
1	3	1	105	70.6	58.8
1	3	2	105	61	56.6
1	3	3	105	68.2	55.2
2	0	3	105	46.6	43.2
2	0	1	105	37.3	44.6
2	0	2	105	43.9	45.2
2	3	3	105	73.2	56.4
2	3	2	105	77.5	60
2	3	1	105	81.1	61.7
2	2	1	105	68.2	56.8
2	2	2	105	74.4	58.1
2	2	3	105	71.7	57.9
2	1	1	105	47.5	44.6
2	1	3	105	57.8	42.3
2	1	2	105	57.1	45.7
3	3	3	105	70.6	60.6
3	3	1	105	70.1	62.4
3	3	2	105	81.1	62.8
3	1	1	105	52	49.3
3	1	2	105	56.7	47.3
3	1	3	105	60.1	45

1	2	2	49	20.8	30.8
1	2	3	49	19.6	29.2
1	2	1	49	27.2	42.4
1	3	1	49	21.8	34.4
1	3	2	49	26.6	36.5
1	3	3	49	23.2	36.5

2	2	1	77	40.9	54.2
2	2	2	77	51	57.4
2	2	3	77	47.5	56.3
2	1	1	77	32.2	43.2
2	1	3	77	31.3	40.3
2	1	2	77	32.2	43.2

3	2	2	105	70.6	56.8
3	2	1	105	70	59.2
3	2	3	105	82.1	58.1
3	0	3	105	44.2	41
3	0	1	105	41.1	42.6
3	0	2	105	38.8	41.6

APPENDIX VI - CROP YIELD DATA

Block	Fertilizer Level	Spacing	No. of Tillers	No. of Heads	Biomass/Plot (kg)	Grain Wt /Plant (g)	Plant Wt/plot (g)	Grain Y/ha (kg)
1	1	3	4	7	2.4	2.8	1246	1385
1	1	1	4	6	1.7	2.8	623	692
1	1	2	6	7	2.6	3.3	986	1096
1	0	1	5	5	1.2	2.2	497	552
1	0	2	6	6	1.6	2.2	665	739
1	0	3	4	4	1.9	1.9	839	933
1	2	2	6	8	1.7	2.5	741	823
1	2	3	5	6	3.2	3	1346	1496
1	2	1	6	8	2.1	3.6	815	906
1	3	1	7	10	2.5	4.2	943	1048
1	3	2	7	9	3	4	1196	1329
1	3	3	7	10	4.5	4.1	1856	2062
2	0	3	4	4	2	1.8	829	922
2	0	1	4	5	1.3	2.3	516	574
2	0	2	6	6	1.8	2.5	748	831
2	3	3	7	9	4.1	3.9	1732	1924
2	3	2	7	9	3	4.1	1214	1349
2	3	1	7	10	2.3	4.1	919	1021
2	2	1	6	8	2.3	3.7	841	934
2	2	2	6	8	1.9	2.6	772	857
2	2	3	5	5	2.8	2.8	1267	1408
2	1	1	5	7	1.7	3	674	749
2	1	3	4	7	3	2.8	1278	1421
2	1	2	6	7	2.4	3.4	1018	1131
3	3	3	7	9	3.9	3.8	1705	1894
3	3	1	7	10	2.2	3.9	880	978
3	3	2	6	9	2.6	3.7	1097	1219
3	1	1	5	6	1.7	2.9	645	717
3	1	2	6	7	2.1	3.1	931	1035
3	1	3	4	7	2.9	2.9	1311	1457
3	2	2	6	8	1.7	2.6	771	857
3	2	1	6	8	2.3	3.8	859	954
3	2	3	4	5	3.4	2.9	1312	1458
3	0	3	4	4	2	2	895	995
3	0	1	4	4	1.3	2.1	475	528
3	0	2	6	6	1.6	2.3	690	767