# FORAGE MINERAL MICRONUTRIENT DENSITY QUALITY IN THE QUARTIN CLOVER (*Trifolium quartinianum*,) UNDER DIFFERENT PHOSPHATE AND SOIL CONDITIONS

**BY**

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## DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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## DEDICATION

My special dedication goes to my mother, Jedidah Wanjiku Kihara who struggled to see me go to school although she had not done so herself and to the memory of my late father Naphtali Kihara who never lived to see me go to school.

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**ABSTRACT**

A study was conducted at Kabete campus field station between September 2006 and June 2007 to determine the herbage growth and forage micro-minerals density of the Quartin clover (*Trifolium quartnianum*) which belongs to the African clover genus. It was assessed for its mineral micronutrient concentration using X-Ray florescence spectroscopy. The study involved three experiments; one in the green house (GH), another one in wooden boxes (WB) measuring $1M^2$ square and the third study in an open field. Soil at the experimental site was randomly sampled and analyzed for micronutrient concentration. The field experiment was laid in Randomized Complete Block Design (RCBD) with four treatments replicated four times. The treatments in the field experiment were:-three terrain levels and Phosphate fertilizer at 0kg/ha $P_20_{5,}$ 30kg/ha $P_20_5$, 50kg/ha $P_20_5$, 60kg/ha $P_20_{5.}$ The first two experiments were done in the green house in pots and in wooden boxes in April 2006 to September 2006 to assess the herbage growth of Quartin clover, four growth stages were observed. Seed was scarified before planting. Plant sampling and data collection were done bi-weekly during the growing seasons to determine herbage growth. The Plant tissues and Soil samples were subjected to Energy Dispersive X-Ray Florescence Spectroscopy (EDXRF) analysis to determine mineral micronutrient concentration. Growth components measured included, plant height, ground cover, leave number, branching, nodule formation, dry matter and seed yield. The date of 50% flowering was 120 days after sowing which gave an indication of how long the legumes take to flower as this is an important criterion for identifying suitable time for harvesting the forage.

Seed emergence was 82-93.0 % 10 days after planting. The good germination percentage was enhanced by seed scarification to remove seed dormancy. SPSS Package version 11.5 was used to analyze the data collected. Data was subjected to ANOVA. Means were separated using the least squire significance difference test at $P \leq 0.05$.

Terrain level and fertilizer treatments showed significant difference ($P \leq 0.05$) in Percent ground cover in field establishment. Phosphate fertilizer application showed significant effects ($P \leq 0.05$) on stubble weight, leaf number and nodules per plant at 50kg/ha $P_20_5$ but there were no differences in plant height due to fertilizer treatments. Stubble weight, dry matter yield and seed yield, were significantly ($P \leq 0.05$) affected by terrain levels in field experiment and box establishment. Iron was the highest mineral micronutrient concentration in Quartin clover seeds followed by Manganese and Zinc respectively. Application of triple supper phosphate at 50kg/ha $P_2O_5$ gave the highest dry matter yield. Herbage growth at the lower slant terrain did better than middle and upper slants (terrain levels) with a positive correlation of r= 0.45 between slants correlated to soils available, Herbage growth was reduced in the upper and middle slants when precipitation was insufficient. Quartin clover responded to fertilizer application since native fertilizer was not adequate to the crop yield permitted by the moisture regime. It therefore recommended that timely planting and/or frequent irrigation is necessary to maximize yield. Quartin clover is a legume fodder that fixes its own Nitrogen and accumulates high levels of protein and micro nutrients. Therefore, farmers interested in restoring soil nutrients in their immediate needy fields could plant it as a cheap method of soil improvement and conservation as well as reducing labour demand in fetching animal feed for zero grazing farming systems. Feeding it to dairy animals would improve the quality

of animal products such as meet and milk hence satisfying the hidden hunger directly to the animals and indirectly to human beings. Phosphate application is of crucial importance in establishment, growth and development of Quartin clover since it affects both herbage growth and mineral micronutrient accumulation in Quartin clover. This study therefore recommends that phosphate fertilizer be applied as a basal fertilizer at a rate of 30-50 kg/ha $P_2O_5$ during establishment of the Quartin clover.

## LIST OF TERMS AND ACRONYMS USED AND THEIR DEFINATION

| | |
|---|---|
| **ANOVA** | Analysis of Variance |
| **BNF** | Biological Nitrogen Fixation |
| **DAS** | Days after sowing |
| **DMD** | Dry Matter Digestibility |
| **EDXRFS** | Energy dispersive X-Ray florescence spectroscopy |
| **GDP** | Gross domestic product |
| **GH** | Green house |
| **KARI** | Kenya Agricultural Research Institute |
| **Kg/Ha** | Kilograms per hectare |
| **LH 1** | Lower highland 1 |
| **LSD** | Least significant difference |
| **LST** | Lower slant terrain |
| **MN** | Manganese |
| **MCA** | Multichannel Analyzer |
| **MST** | Middle slant terrain |
| **N** | Nitrogen |
| **RCBD** | Randomized Complete Block Design |
| **SOM** | Soil Organic Matter |
| **SPSS** | Statistical package for social scientists |
| **TSP** | Triple Super Phosphate |
| **UST** | Upper Slant Terrain |
| **WB** | Wooden boxes |
| **EDXRF** | Energy Dispersive X-Ray Florescence Spectroscopy |

**TABLES OF CONTENTS**

## LIST OF FIGURES

## LIST OF TABLES

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background information

A rich diversity of African clover is distributed in African highlands across a wide range of soil types present across the uplands and bottomland catena and their agronomic potential has been demonstrated for intensified forage-crop-livestock production (Bogdan, 1968; Kahuranaga *et, al.*, 1984). There are 10-20 perennial species and numerous annual species occurring in Ethiopia region alone and they are common highlands components of natural grass and pastures in the region (Akundabweni, 1986). The Mediterranean region is the primary center of diversity of clovers. However there are a number of secondary centers of diversity in Africa including central Ethiopia, Somalia, Tanzania and Kenya (Zohary 1972). African clovers are either annuals or perennials. African annual clover (Quartin clover) here after referred to as Quartin clover is endemic to Ethiopia and was selected from the Ethiopian highlands (Akundabweni, 1986). Its agronomic performance was studied both in Ethiopia and in Kenya. It has been found to have high protein content which has been studied for zero grazing farming systems (Akundabweni, 1984).

Research over the past few decades has revealed enormous potential in forage legumes for increasing both crop and livestock production (Hague and Jutzi, 1985). In cropping systems, forage legumes are a cheap source of nitrogen whose presence in the soil boosts crop yield. Quartin clover was advanced as an ecotype by Akundabweni (unpublished) has shown excellent agronomic performance; rapid maturity, high biomass production, high nitrogen content in leaves, pests and diseases tolerance, rapid ground cover, weed suppression, easy establishment from seeds and possible alternative uses such as biological nitrogen fixation, mulching effect, soil and water conservation (Akundabweni, 1984; Muthoni and Akundabweni, 2005, Lupwayi *et al*., 1997). Quartin clover was shown to elicit high dry matter yield with good nutritive quality (Akundabweni, 1984). It is highly palatable and has no reported antiquality substances (Akundabweni, 1998), but there is no information on the micro nutrient density.

Trifolium species are forage legumes whose traits have been evaluated by scientists and plant breeders in conjunction with International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia working closely with National Agricultural Research System (NARS) and International Livestock Research Institute (ILRI) both located in Nairobi, Kenya (Lupwayi *et al*., 1996).

Since shifting cultivation is not practical today due to increased population, legume crops such Quartin clover can be used as a practical way of replenishing soil nutrition, crop and animal productivity (Lupwayi *et al*., 1996). Most farmers in the small hold farms are resource poor and cannot afford to buy mineral fertilizers to apply in their farms (Titonell *et al*., 2005).

There is limited information reported on qualities of Quartin clover since it's identification by Bogdan in 1953. Until recently little was known about it's agronomy until work of Akundabweni (Akundabweni, 1984). He showed it as promising on a moderately drained to well drained soils with high dry matter production under well distributed rainfall. It is thus a special and unique ecotype with high biomass production. Further work was done to select the seed by removing the individual plants that were not performing well and leaving seeds for plants that showed superior agronomic characteristics (Akundabweni *et al*., (1991). However Quartin clover has to date not been adopted in arable agriculture since it is a feed rather than a food crop. But it appears to have some promise if it can be incorporated into intercrop with wheat as was shown at Holetta in Ethiopia (Kahurananga *et al*., 1984). The constraint is that seed field is in limited amount because it is a shy seed producer. However, dormant seeds are capable of staying in the seed bank for several years before they emerge again after the brack down of the dormancy (Akundabweni Personal Communication). Although Macro-nutrient e.g. crude protein are known, mineral micronutrients concentrations are little. Thus this study gave attention to mineral micronutrients quality of Quartin clover starting with the seed itself.

Forage mineral content depends much on the soil on which the particular crop is grown and the amount and the type of fertilizer applied. Problems with trace elements such as

Copper, Cobalt and Selenium could become more common if greater reliance is placed on home-grown feeds and less on bought feed which generally contain mineral supplements (Raymond *et al*., 1986). It would be advisable to decide on such supplementary feeding in consultation with a nutrition adviser, who can take account of the mineral content of the forage grown on that particular farm and on the other feeds likely to be fed. Therefore, some nutritional understanding will be increasingly important to the livestock farmer seeking to adopt the most profitable way of feeding his animals (Raymond *et al*., 1986).

No study has shown mineral micronutrients quality especially demonstrating the quality in seed and soil and how they vary according to the terrain on the soil and how they vary in dry matter yield. This study determined the mineral micronutrients concentration in young seedlings, up to eight (8) weeks of herbage growth in order to assess the mineral micronutrients status of the clover as influenced by the terrain level soil characteristics at Kabete field station experimental site. This was achieved through testing the mineral micronutrients density in the seeds, their accumulation in forage of young seedlings up to eight weeks of growth and the soil.

## 1.2 Problem statement

Poor feed nutritive value in the crop residuals and in the grasses in drier seasons leads to low productivity. Inadequate quantity and poor quality in fodder is a major limitation to livestock production because crop residues are generally inadequate animal feed and needs supplementation (Mosi, 1983). It is, therefore imperative to introduce fodder legumes of high nutritive value, which can be used to supplement feed for farm animals.

Quartin clover is a recently developed forage cultivar with promise. It is adapted to Eastern African highlands ecology which is rich in crude protein, carbohydrates and digestible fibre. However, its mineral micronutrients density and effects on contribution to satisfying hidden hunger in grazing animals is not known.

## 1.3 Justification

Annual African clover (Quartin clover) is a newly developed forage legume that has been extensively studied for its agronomic performance and adaptation stability as a forage legume. It has shown promise for incorporation into the intensively cultivated smallholder mixed farming systems that are intended to meet an increasing food requirement for an ever increasing population. Over cropping, nutrient mining, soil erosion and mineral leaching have led to decline in soil fertility and low productivity in these small holder farms in the Kenya highlands. Quartin clover has also been shown to have high crude protein and high percent dry matter digestibility (%DMD), but there is little or no information about its mineral micronutrients density in both the seeds and the forage. Therefore, there was need to conduct this experiment on its mineral micronutrients density nutritive quality in Kabete Humic Nitosols where its agronomic potential has been previously studied. This clover has not been incorporated into the cultivation systems because it is unknown farmers. If its adopted into zero grazing systems, it would be an ideal clover as a source of forage legume not only to provide protein but high mineral micronutrients and be a complement that can reduce cost of mineral supplements. If this promising clover continues to be ignored it will disappear from the gene pool and become extinct. Thus it is appropriate that clovers such as Quartin clover are assessed in terms of their mineral micronutrients value particularly as abases of appeal for zero grazing into intensely cultivated systems for saving on purchased mineral supplementation.

### I.4 Conceptual framework

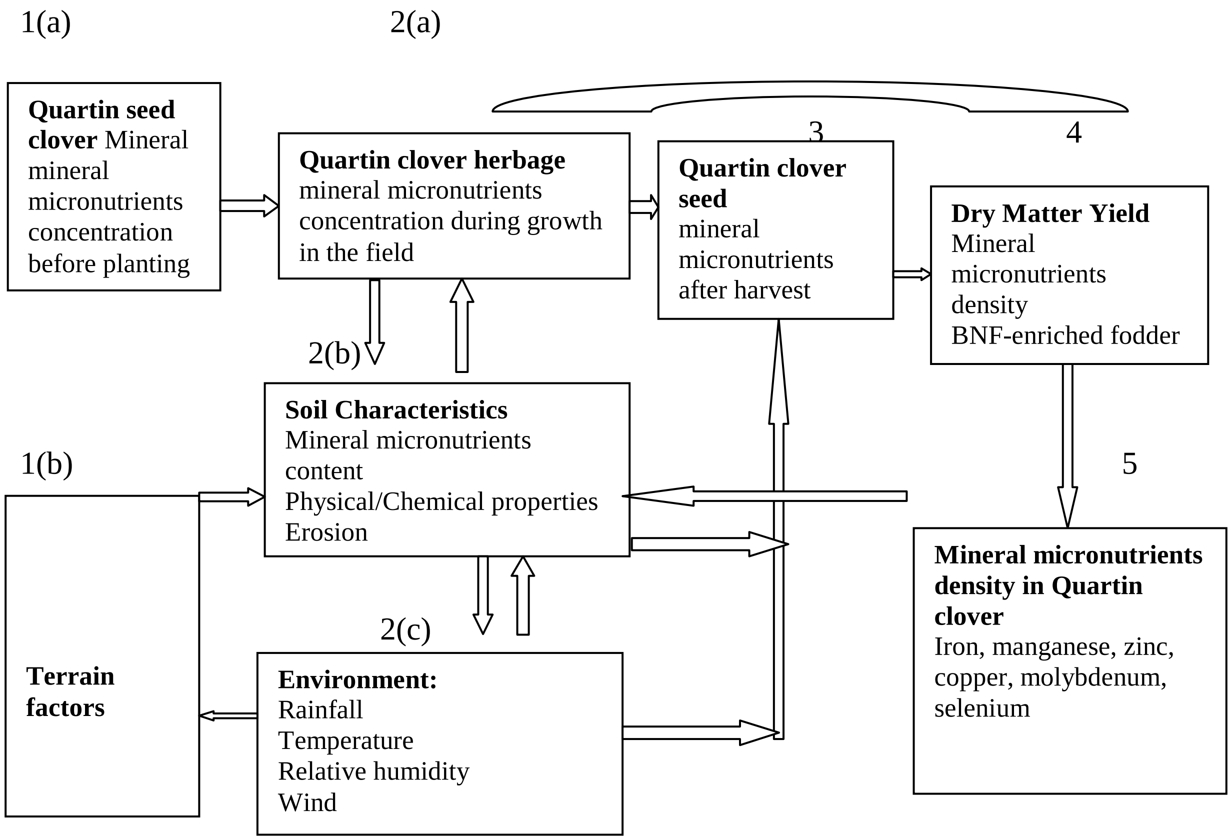



**Fig.1. Conceptual framework illustrating herbage growth of Quartin clover as it interacts with above and below ground environment**

*1(a): Germplasm acquisition level: Micro nutrient as a result of uptake history and inherent genetic potential (starting point)*

*1(b): Terrain environment as affected by (2c- environmental conditions) and a factor on the physio-chemical characteristics (2b-terrain factors) which in turn affects minerals mineral micronutrients flow between the soil and the plant.*

*2(a): Leafy/vegetative mineral micronutrients uptake from the soil during growing season*

*3: The experimental site specific seasonal effect 0n seed mineral micronutrients density in event that genotype environment effects were strong*

*4: For zero grazing quantity and quality at the cutting stage*

*5: The beneficial dependent variable*

## 1.5 Broad Objective

To assess the herbage growth and mineral micronutrients density in Quartin clover seedlings as influenced by terrain position and phosphate status on Kabete Nitosols.

## 1.6 Specific Objective

The specific objectives of this study are to:

1. Assess the herbage growth of Quartin clover planted along three terrain gradients on Kabete soil.
2. Determine the mineral micronutrients density in Quartin clover  seeds crop, and seedlings in the 2-4- 6 and 8 week stage of growth and development in relation to the site terrain mineral status.
3. Determine the effects of Phosphate on mineral micronutrients density in Quartin seedlings up to the $8^{th}$ week of growth.
4. Compare the herbage yield of Quartin clover across three established environments (i.e. Greenhouse potting, open air boxes and field).

## 1.7 Research Hypothesis

1. There are no differences in the performance of Quartin clover due to terrain levels (slants)
2. Quartin clover remains with similar levels of mineral micronutrients in both the seeds and the seedlings.
3. Phosphate fertilizer has no effect on mineral micronutrients accumulation in Quartin clover's seedling stage.
4. There are no differences in the herbage yield due to plant establishment under soil environments.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Pasture legumes

Annual forage legumes are recognized for their potential in production of high protein feed from fallow land. They can be used to for grazing, harvested for hay or harvested for grains and straw at maturity. Skerman *et al*., (1998) gave the following characteristics as essential for successful tropical pasture legumes: Efficient nitrogen fixation, tolerance to range of soil conditions, high production of seeds that can be harvested easily, resistance to diseases and pests, high feeding value throughout the growth period and persistence.

Some of the essential qualities of pasture legumes are: persistence and aggressive in addition to high yields, palatability, Nutritive value and adaptability to withstand stress (Prasad, 1995). Pamo and Mubeteneh, (1995) added that the legumes ability to frequently root at nodes when in contact with the soil enables maximum use of soil nutrients hence making such legumes very aggressive and better competitors to weeds.

The tissue elemental concentration variation in plants is based on genetic differences among species and the species extent of uptake from the soil. Due to their genetic differences and species extent of uptake, tissue concentration varies (Shacklette, 1980). With respect to these variations, there possibly exists a genetic diversity in phyto-mineral micronutrients density.

The time of harvesting of Quartin clover has very pronounced effect on forage quality. As the plant matures, both the ether extract and the crude protein values fall, while the crude fibre and the nitrogen free extractive value rises. Leaves contain high levels of crude protein and other extracts while the stem has values for nitrogen-free extracts' fraction (which contain hemi cellulose) and for the crude fibre component (Shacklette, 1980). Although there is no time of rapid elongation for legumes, these species do undergo substantial stem thickening and marked increase in stem weight takes place before flowering. Percent of leaves by weight before and at the time of flowering is lower for legumes. It takes a longer period for legume crude protein of these tissues to fall below 6.5% the lower threshold for animal maintenance (t'Mannetje *et al*., 1980). Njarui and Wandera, (1997) observed that for the technology to be accepted by farmers, the legume should produce a reasonable amount of herbage and be compatible with the companion grass.

Biologically available nitrogen forms only a minute fraction of the total present earth's crust, furthermore much of this nitrogen is inaccessible to plants and as it is present in the forms of dead organic matter from where it is slowly released by microbial action. Nature reacts to this by recycling combined nitrogen in a complex process known as ‘Nitrogen cycle’ (Delwichie, 1977). Forage legumes have potential to contribute to farming systems through nitrogen fixation in the soil when they form root nodules. The amount of Nitrogen fixed by the legume component in a legume cereal intercrop system depends on several factors, including the legume species, plant morphology, density of the component crops, type of management as well as the competitive ability of the component crops (Fujita *et al*., 1992). African  are legme forage found naturally growing in pasture lands in combination with grasses.

**2.2 African Clovers**

African clovers are distributed in African highlands across a wide range of soil types present across the uplands and bottomland catena and their agronomic potential has been demonstrated for intensified forage-crop-livestock production (Kahuranaga e*t al*., 1984), with Ethiopian highlands having the greatest diversity. There are both annual and perennial African clover species. There are 10-20 perennial species and numerous annual species occurring in Ethiopia region alone and they are common highlands components of natural grass and pastures in the region (Akundabweni, 1986). Perennial clovers have variable habits and a strong tap root system especially the ones that are indigenous to Eastern African highlands and more commonly found in moist places (1800m to 3700m elevations with a rainfall amount of 1000mm and above) Kamal, (1989). Cool areas with long favorable moisture spell should be suitable for the growth of some promising African clovers (Akundabweni *et al*., 1991).

Trifolium species can be incorporated in conversational farming beside their value as high quality animal feed. They have promise as forage in highlands for feed production, and for soil improvement and water conservation as a cover crop. The primary center of diversity of clovers is the Mediterranean region. There are a number of secondary centers of diversity in Africa including central Ethiopia, Somalia, Tanzania and Kenya (Zohary 1972). African clovers are endemic to Ethiopia of which two thirds are annuals and the remainder is perennials. There are no biennials identified in Ethiopia valley bottoms that are not cultivated due to seasonal water logging which are natural habitats for some clover species, thus they can be managed to improve forage production without competing with food crops for land especially to annual clovers which can easily be eradicated (Friedericks *et al*., 1991).

Since 1980s the International Livestock Center for Africa formally (ILCA) has focused its research on the Eastern African highlands clovers as it realized the potential of clover in the farming systems of Sub-Saharan Africa. *Trifolium quartinianum, Trifolium steudneri, Trifolium tembense*, and *Trifolium decorum* among others showed high dry matter yield with good nutritive potential (Akundabweni, (1984) and economic seed production (Akundabweni and Njuguna 1996). Some clovers tested in the Ethiopian highlands showed to have good forage yield (Kahurananga and Tseley, 1984). Seed production in Quartin clover was shown to require high temperatures of $23^{o}$c and above. Quartin clover performed well as expected between 18 $^{o}$C - 25 $^{o}$C temperature ranges which confirmed it as a highlands legume Akundabweni (1986).

African annual clovers have now extensively been documented to possess excellent, forage potential for livestock (Kahurananga *et al*., 1986). These clovers are distributed in the African highlands across a wide range of soil types from uplands to bottom land catena (Bogdan, 1968). Some of these species such as *Trifolium tembense* are exceptionally adapted to waterlogged conditions withstanding partial submergence especially under high soil fertility. The legume thrives well on long duration retained soil moisture, which is a characteristic of heavier bottomland soils (Akundabweni *et al*., 1991).

Mannetje (1997) and Skerman (1977) reported that Quartin clover can produce dry matter yield of 1800-7500kg/ ha. Quartin clover is the most productive of the native Ethiopian clovers with vigorous growth that can produce 7800kg $ha^{-1}$ dry matter within 3 months when the growing conditions are favourable (Kahurananga, J. and Tsehay, 1991). The clover has shown high nutritive value and can be used as feed supplement in dairy faming since most tropical grass pastures tend to decline in nutritive value with increase in maturity (Olayiwole *et al*., 1986). It grows with vigor; and has capacity to regenerate, and with high palatability. Quartin clover has ability to compete for water and nutrients. However the mineral micronutrients concentration has not been studied. It is a known fact that animal mineral micronutrient are more readily bio available for human than plant mineral micronutrient. In effect therefore, if certain fodder species can efficiently accumulates the categories shown in table 4 to be passed on to grazing livestock, their milk can be expected to be mineral micronutrient density prospect for an even higher mineral micronutrient enrichment of goat milk regarded as medicinal in Kenya could appeal for the inclusion of Quartin clover into small holder systems

## 2.3 Terrain characteristics

### 2.3.1 Soil moisture regime

Soil condition and climate are factors that influence not only growth but also subsequent dry matter yield accumulation and nutritive quality of clover (Kahurananga *et al*., 1984). Akundabweni, (1984) however, observed that some soils, which rapidly lose water tend to succumb to drought more quickly than slow water losing soils. In his experiment, he found that the set of loose soil did poorly compared heavier ones. Later studies showed that seed yield obtained from *Trifolium tembense* when grown in Kabete well-drained Nitosols was low. This result was attributed to short rainfall duration when compared to Shola soils in Ethiopia (Akundabweni and Njuguna, 1996). The study revealed that the essential effect of soil seems to relate to the number of rainy days and soil moisture retention influenced by terrain gradient.

Gachene *et al*. (1997) noted that mucuna pruriens had a shading effect indicating that good ground cover (live and dead mulch) minimizes losses of water and minerals through leaching and evaporation. The addition of soil organic matter by legume through death of leaves and other plant parts has also the positive effect on conservation of soil and moisture through protection of the soil surface (Sanginga *et al*., 1992). They also observed that the indirect effects of soil organic matter on water dynamics operate mainly through the increase in water holding capacity of the soil. Access of plants to water depends on soils capacity to hold water for a given period of time (McWilliam, 1978). Field experiments have shown proneness of African clover to wilting under water stress particularly in hot and dry weather conditions. This explains why frequent irrigation is recommended if the crop is not growing under sufficient water condition to obtain maximum yield (Akundabweni, 1996; Wondafrash, 1999). Soil moisture condition depends on annual rainfall and soil acts as a medium of exchange of water. Kahurananga and Tesley (1984) indicated that forage yield of annual African clover was less sensitive to rainfall at the site of origin. It was further observed that the native clover from high rainfall area subsequently show high yield (Kahurananga and Tseley 1984; Akundabweni1984).

Akundabweni *et al*., (1991) indicated that the number of moist days after planting has more significance in the management of the Quartin clover for optimum productivity than calendar days after planting as the distribution rather than intensity. Kahurananga, (1991) observed that rainfall distribution made both wheat and clover grow well which was in agreements with the findings of Akundabweni *et al*., (1991). Water stress increase the ratio of shoot/root (Wondafrash, 1999) and premature ripening is likely to occur and growth period ended sooner or later if mid-year planting rainfall is not supplemented for by irrigation (Akundabweni *et al*., 1993). They also found out that annual African clover has a leaf area index of more than 5 compared to beans, which have (LAI of 5) hence clover has great exposure to increased transpiration loss. Seasonal pattern of soil moisture for plants evapo-transpiration is important because it determines the severity of principal constraints in agriculture. When the amount of precipitation is locally insufficient, crop growth is reduced since the crop may not respond to fertilizer addition if native fertilizer is adequate to produce the crop yield permitted by the moisture regime.

### 2.3.2 Soil fertility

One major objective of chemical inventory of the soils on which crops are grown is to determine its ability to supply essential elements in the right proportions and in adequate amounts throughout the growing season (Giller *et al*., 2005). Identifying and modelling variations in soil fertility at farm level have rarely been used for practical management to increase nutrient use efficiency (Tabu, 2003). The inherently infertile soils coupled with critical nutrient mining in farmers fields implies that external fertilizer has to be applied if optimal crop yield is to be achieved based on soil type. The limitation is pronounced in soils with low organic matter and dominates in medium and high potential areas of Kenya (Sanchez *et al*., 1997). A survey of fertilizer use however shows that farmers use sub-optimal levels of fertilizer probably because of poor resource level and non specific recommendations that aim at optimizing crop yield but necessarily nutrient use efficiency (Smaling and Broun,1996; Mose *et al*.,1996; Giller *et al*., 2005). However, small scale farmers use variations in soil fertility to maximize crop yield (Murage *et al*., 2000; Titonell *et al*., 2005). Therefore the soil interplay of the physiochemical factors is likely to be of crucial importance in the natural selection of African clover, the adaptation performance, the ultimate yield and forage quality

The Nitrogen fixing legumes offer low cost opportunity for maintaining soil fertility by improving nitrogen supply to the soil, they provide protective ground cover, conserve soil moisture, reduce soil erosion and low cost for weeding (Gachene *et al*., 1991). Nitrogen can then be passed on to the soil through root nodules decay (Vallis and Gardiner, 1984) and mineralization of organic matter from dead plant material and from animal feaces and urine (Mannetje, 1997).

Legumes enhance food security, soil and water conservation by reducing soil loss by surface run off and their ability to cover the soil reducing evaporation and enhancing infiltration (Gachene *et al*., 1991). They rehabilitate degraded land (an issue that should be given priority) and are very important in biological nitrogen fixation. The capacity of BNF varies with the legume species, the environment and the management practices (Tothill, 1990).

Until the advent of sophisticated analytical techniques, most plant diagnostic relied upon visual deficiency symptoms, crop history, soil series, soil pH and other variables as guides in identifying mineral micronutrients disorders (Donahue et al, 1983). Site Specific Nutrient management (SSNM) has to be used if under or over application in some areas of the farmers field is to be avoided ( Verhagen and Bouma, 1997). Farmers local knowledge is cost effective and could be pertinent to the implementation of site-specific nutrient management (Fleming *et al*., 1999)

The appropriate content of minerals in plants is essential both for health of the plant and the nutrient supply to man and animals that feed on them. Soils supply plants with organic mineral nutrients in the form of dissolved ions. The plant takes these elements out of the soil solution and incorporates them into the thousands of different organic compounds that constitute plant tissue. A fundamental role of soil in supporting plant growth is to provide a continued supply of these minerals in amounts and proportions appropriate for plant growth (Underwood, 1999).

The concentration of nutrients in plant tissues seems to be a function of soil mineral status. Pattern of this however differs among the plant species and plant parts (Kabata and Pendias, 1984).

Quartin clover was therefore established on three terrain levels to find out the relationship between mineral micronutrients concentration in the soil and in plant tissues

**2.3. 3 Phosphorous in legumes**

Phosphate fertilizer application increased dry matter yield, leaf nitrogen and phosphorous level of runner bean (Kahuro, 1990). Reneau et al., (1983) working on sorghum reported that phosphorus fertilizer increased nitrogen concentration sorghum. Application of phosphorous has been shown to increase dry matter yield, percent phosphorus of pasture legumes and nitrogen in pasture legumes (Muthoni, 2000). Phosphorus has been shown to increase dry matter yield of annual clover (Haque and Lupwayi, 1998, 1999; Mugwira et al., 1997; Haque and Mugwira , 1991; Kahurananga,1991; Kong et al., 1993; Akundabweni, 1984a, 1984b). Application of phosphorous has been shown to increase

Iron concentration in the tissues through enhanced root and herbage tissues development; dry matter (Haque and Lapwayi, 1998; Kong et al., 1993). The current study, aimed at finding out if application of phosphorous could affect uptake and accumulation mineral micronutrients in Quartin clover.

### 2.3.4 The terrain levels at the experiment site in Kabete field station

The source of nutrient capital reserves in the soil is weatherable minerals from dissolution of basal rocks (Sanchez *et al*., 1996) and soil organic matter (SOM), which contains a lot of nitrogen, phosphorous and sulphur (Vallis and gardner, 1984). The key soil erosion control is to keep the land covered with plants throughout the year.

The field experiment was laid on a sloppy farm between 5 and 15% gradient which was divided into three slants namely: upper slant terrain 2-5% gradient, middle slant terrain5-15% and 0-5% gradient lower slant terrain as shown in figure 2 below.

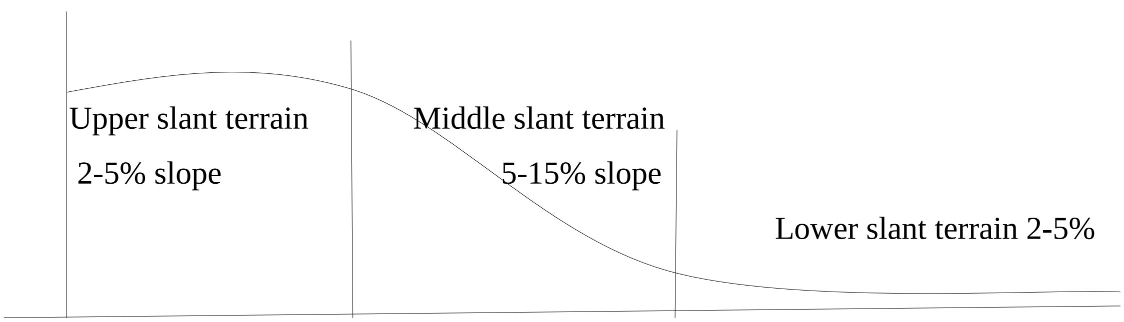



**Fig. 2 The terrain gradient at the experiment site showing the percent slope.**

The middle slant terrain at the experiment site was prone to soil erosion due to the high gradient while most of the eroded soil is usually deposited at the lower slant terrain making it more fertile than other slants. Gachene *et al*., (1996) found that a two year erosion period for a humic nitosol at Kabete Kenya was enough to cause a 64% loss in maize grain yield in the most eroded plots.

### 2.3.5 Mineral micro nutrients in the soil

Micronutrient elements form part of the animal body. Unless they are present in adequate amounts, animal begin to suffer from hidden hunger, especially human. In regions with soils deficient with certain minerals, supplemental feeding or manure application in pastures with the deficient element will both increase production and prevent disease (Fraser and Stamp 1987). There are 16 essential mineral elements for animals. Calcium, Phosphorous, Potassium, Sodium Chlorine, Sulphur and Magnesium are major elements (Rook and Thomas 1983; Cole, and Haresigh 1985), and Iron, Iodine, Copper, Manganese, Zinc Cobalt, Molybdenum, Selenium, and Chromium as trace element (Rook and Thomas 1983). There is a growing awareness of the need for knowing the trace elements content in soils and plants. Although only required in small amounts by plants and humans, trace elements deficiencies can have just as much effect as of macronutrient elements deficiencies on human and plants. Some of the necessary elements, when included in the diet at too high levels may be toxic. Thus, some of the mineral micronutrients are discussed in this below: The mineral micronutrients of interest are underlined in Table 2.1

**Table 2.1. Trace elements established essential according to their nutrient value**

| [a]Major/Macro | [b]Trace/Micro | [c]Ultra-trace | [d]Beneficial |
|---|---|---|---|
| Calcium | <u>Zinc</u> | Boron | Barium |
| Phosphorus | <u>Iron</u> | <u>Molybdenum</u> | Bromine |
| Magnesium | Silicon | <u>Selenium</u> | Cadmium |
| Sulphur | <u>Manganese</u> | Nickel | Lead |
| Potassium | <u>Copper</u> | Vanadium | Lithium |
| Chloride | Fluoride | Arsenic | Tin |
| Sodium | <u>Iodine</u> | <u>Cobalt</u> | |
| | Chromium | | |

[a] Needed in amounts greater than 100 mg per day and represent 1% or less of body weight.

[b] Essential in much smaller amounts, less than 100 mg / day and makes up less than 0.01% of body weight.

[c] Required in amounts of less than 50 ng/g in diet of animals.

[d] May contribute to biological processes but essentiality not yet established.

(Source: Encyclopaedia of Food Science and Technology, Vol. 5 1993).

### Iron

Iron is a metallic chemical element that is the fourth most abundant element in the earth's crust. It constitutes about 5% by weight and is believed to be the major component of the earth's core. Iron is found distributed in the soil, and dissolved in ground and ocean waters to a limited extent. It is rarely found uncombined in nature, but iron ores and minerals are abundant and widely distributed. Iron is biologically significant (Cole and Haresigh, 1985). Iron is an essential component of hemoglobin, a red oxygen-carrying pigment of the red blood cells of vertebrates and muscle pigment myoglobin, iron compounds are important in nutrition. Iron is a requirement in animals. Some body enzymes also have a composition, which include iron. Deficiency of iron causes anemia.

### Iodine

Iodine, a nonmetallic chemical element, symbol I, is a dark-gray to purple-black, lustrous, solid element with a rhombic crystalline structure. It is the least active of the halogens. When heated it passes directly from the solid to the vapor state. The element is obtained from salt deposits and from salt brines. Iodine is important in medical treatment and in small amounts is essential to human nutrition. In the thyroid gland it becomes a part of the iodine-containing hormones, which regulate the rate of energy metabolism in the body (Welch *et al*, 1991, Hetzel, 1986, Hetzel and Marberly, 1986). Between 70 and 80 percent of dietary iodine is absorbed as iodide from the rumen with considerable resecretion occurring in the abomasum (Miller *et al*., 1988). Iodide that is secreted into the abomasum is largely reabsorbed from the small and large intestine. Absorbed iodide is largely taken up by the thyroid gland for thyroid hormone synthesis or is excreted in the urine. In lactating cows, approximately 8 percent of dietary iodine is secreted in milk (Miller et *al*., 1988). Iodine is an essential component of the hormone thyroxin. Its deficiency leads to an enlargement of the thyroid gland particularly in lambs at birth, referred to as goiter, a swelling of the thyroid, is often a symptom of inadequate iodine in the diet. This is followed by depression of all productive functions and lambs are often stillborn or weakly (Charles, 1983).

**Cobalt**

Cobalt is an essential component of Vitamin $B_{12}$ which is manufactured by rumen micro flora. A deficiency leads to depression of all productive functions; perhaps most notably stunt growth, anemia and stillborn lambs. The ruminal flora does not have any store of cobalt available and so daily intake is necessary (Charles, A.B. 1983; Nickerson, 1978).

**Manganese**

Manganese is a pinkish-gray metallic chemical element, symbol Mn, and is the first element in-group VII of the periodic table. Manganese is found in abundance in nature and is Manganese is an essential trace nutrient in all forms of life. Manganese is needed as a nutrient in small amounts by many plants and animals and by humans. Manganese has been shown experimentally to be necessary for normal skeletal development in sheep but deficiencies have not been found under grazing conditions (Charles, 1983). As little as 0.5mg/kg of dietary dry matter is sufficient to maintain good growth rate and feed gain ratio in pigs from birth to 90kg live-weight (Fraser and Stamp 1987). The classes of enzymes that have manganese cofactors are very broad and include such classes as oxidoreductases, transferases, hydrolases, lyases, isomerases, ligases, lectins, and integrins. and also in many bacteria (this fact is in keeping with the bacterial-origin theory of mitochondria) (Grant *et al*., 1997). Manganese compounds are less toxic than those of other widespread metals such as iron, nickel and copper compounds. However manganese is toxic in excess (Pohanish, 2006) for nearly all organisms living in the presence of oxygen use it to deal with the toxic effects of superoxide, formed from by the 1-electron reduction of dioxygen (Meco *et al*., 1994). Exceptions include a few kinds of bacteria such as *Lactobacillus plantarum* and related lactobacilli, which use a different non-enzymatic mechanism, involving manganese ($Mn^{2+}$) ions complexed with polyphosphate directly for this task, indicating how this function possibly evolved in aerobic life (Mineral research and development institute, 2003).

**Copper**

Copper a metallic chemical element; is present in minute amounts in the animal body and is essential to normal metabolism. The principal ore of copper is chalcopyrite, a sulfide of copper and iron, also called copper pyrite (Lide, ed. 2005)

Copper is an essential trace element in plants and animals, but not some microorganisms (Bonham *et al.*, 2002). Copper is essential in enzymes required for heart function, bone formation, energy metabolism, elastin synthesis, normal hair growth and red blood cell formation. (Encyclopaedia of Food Science and Food Tech., 1993).

Copper is needed for quite a wide variety of body functions. Its deficiency is particularly indicated by in-coordination in newborns lambs and by anemia (Charles, 1983; Fraser and Stamp 1987) and poor growth in adults. Wool is also affected characteristically by a change in color (graying in pigmented wool or change from creamy to chalky in non pigmented wool). Young animals loss crimp and strength giving a typical stringy appearance. Copper is effectively stored in the liver, a reserve that does not usually get depleted for4-6 months in case animals feed in a diet deficient in copper (Charles, 1983). However, particular care has to be taken in feeding copper to animals because high liver levels followed by a sudden stress causes release of copper into the bloodstream resulting into an acute fatal hemolytic jaundice (Nickerson, 1976).. Conversely, Wilson's disease causes an accumulation of copper in body tissues. Severe deficiency can be found by testing for low plasma or serum copper levels, low celluloplasmin, and low red blood cell superoxide dismutase levels; these are not sensitive to marginal copper status. The "Cytochrome c Oxidase activity of leucocytes and platelets" has been stated as another factor in deficiency, but the results have not been confirmed by replication (Bonham, *et al.*, 2002). Copper salts (30 mg/kg) are toxic in animals. A minimum dietary value for healthy growth in rabbits has been reported to be at least 3 ppm in the diet. However, higher concentrations of copper (100 ppm, 200 ppm, or 500 ppm) in the diet of rabbits may favorably influence feed conversion efficiency, growth rates, and carcass dressing percentages (Ayyat *et al.*, 1995).

**Molybdenum**

Molybdenum is an essential trace element for virtually all life forms. It functions as a cofactor for a number of enzymes that catalyze important chemical transformations in the global carbon, nitrogen, and sulfur cycles. Thus, molybdenum-dependent enzymes are not only required for human health, but also for the health of our ecosystem (Lide, D.R., ed. (2005). Molybdenum plays a complex role in animal growth and development. Excess dietary molybdenum has been found to result in copper deficiency in grazing animals (ruminants). In ruminants, the formation of compounds containing sulfur and molybdenum, known as thiomolybdates, appears to prevent the absorption of copper (Jane Higdon, 2001). Small quantities are beneficial. Deficient diet encourages excessive copper storage with the associated risks mentioned above. The balance between molybdenum and copper is also affected by intake of sulfate with high levels increasing the danger of molybdenum toxicity (Nickerson, J.T.R. 1976).

**Zinc**

Zinc compounds are numerous and are widely used. Zinc is essential to the growth of many kinds of organisms, both plant and animal. It is a constituent of insulin, which is used in the treatment of diabetes. Chief sources of zinc are the sulfide ore; Zinc ores are widely and abundantly distributed throughout the world. Zinc is present in all animal tissues and is a component of a number of enzymes. It is required for normal growth and appetite and the functioning of the testes is even more sensitive to deficiencies (Rook &Thomas1983). Zinc deficiency is characterized by growth retardation, loss of appetite, and impaired immune function. In more severe cases, zinc deficiency causes hair loss, diarrhea, delayed sexual maturation, impotence, hypogonadism in males, and eye and skin lesions (Maret and Sandstead, (2006) , Prasad, 2004). Weight loss, delayed healing of wounds, taste abnormalities, and mental lethargy can also occur But these are unlikely in grazing animals (Rook &Thomas1983). Zinc toxicity can occur in both acute and chronic forms. Acute adverse effects of high zinc intake include nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, and headaches and reductions in a copper-containing enzyme (Willis *et al*., 2005)

**Selenium**

Selenium is a nonmetallic chemical element; symbol Se; directly below sulfur in the periodic table. Selenium sometimes occurs in conjunction with sulfur deposits and often occurs as the selenide (especially of copper, lead, silver, and iron) in sulfide ores (National Research Council 1983). Nonetheless, selenium is one of the elements needed in trace amounts in the animal and human diet. Selenium is important for animal muscular development and when deficient leads to degeneration of muscles, particularly of the hindquarters and arthritis (Stone *et al*., 1997). It is in suckling lambs (when muscle development is at the peak) that is the most susceptible to this condition. Selenium is a requirement for cattle. Lack of selenium in certain cattle feed has caused nutritional diseases (Laubuza, 1974). Certain plants may accumulate selenium and when grazing is confined to these, toxic symptoms may occur particularly affecting hoof development and fertility and shedding of fleece (Charles, 1983). While the nutritional value of all plant food depends on the soil in which it was grown, the selenium content of plants seems particularly sensitive to soil concentrations. For this reason, most of the early research on selenium focused on diseases in sheep, cattle, turkeys, and pigs which involved low soil concentrations of selenium and insufficient amounts of selenium in the forage plants eaten by these animals. It is important to remember that the selenium content of food is highly variable because it depends so heavily on soil conditions. While soil conditions affect plant foods most directly, they also affect animal foods, since most animals depend upon plants for their diet. Deficiency symptoms for selenium are difficult to determine and controversial in the research literature (Abrams *et al*., 1992) Intake of selenium that is borderline or only mildly deficient has not been connected with specific symptoms. With prolonged and severe deficiency, symptoms clearly center around two of the body areas where oxidative stress is known to take its toll: the heart and the joints (Badmaev *et al*., 1996). When oxygen-containing molecules become too reactive, they can start damaging the cell structures around them (Diplock, 1992). Selenium helps prevent oxidative stress by working together with a group of nutrients that prevent oxygen molecules from becoming too reactive. This group of nutrients includes vitamin E, vitamin C, glutathione, selenium, and vitamin B3. In many instances of heart disease, for example, where oxidative stress has been shown to be the source of blood vessel damage, low intake of selenium has been identified as a contributing factor to the disease (Diplock, 1992).

The Quartin clover was analyzed for Zinc, Iron, Manganese, Copper, Iodine, Molybdenum, Selenium and Cobalt .Their importance has been demonstrated by the research and needs not to be overemphasized

**2.4 Methodology**

Conventional method of fertility assessment that include soil sampling, laboratory analyses and the state of art (geographical positioning and geographical information systems) methods are slow and/or expensive and not accessible to small scale farmers (Murage *et al*., 2000). Studies in search of low cost effective methods show that farmers use agro-ecological knowledge to allocate crop types to soil fertility niches based on variation in nutrient status and requirements (Giller et al., 2005;Titonell *et al*., 2005; Desbeiz *et al.,* 2004).

Essential trace elements particularly present in unknown materials can be assessed by invitro and instrument based technologies. However, Akundabweni (2010 a, b, c) has successfully applied the XRF instrumentation to assess mineral micronutrients variation in vegetable leafy system with focus on indigenous vegetables. This has been undertaken at the Institute of Nuclear Science and Technology of the University of Nairobi which has developed an Energy Dispersive X-Ray Fluorescence (XRF) spectrometer based on Cd109 radioisotope source for analysis of trace elements. The spectrometer (Fig. 3) is relatively easy to use and in comparison with other techniques it is cheap, flexible and has a superior analytical capacity (Gatari, 2006). Markowicz *et al.,* (1996) observed that it is as an important analytical tool for analyzing elemental samples due to its ability of providing an advantageous compromise between truly multi element characteristics, satisfactory speed, economy and ease of operation.

Trace elements in samples in this study were analyzed by EDXRF spectrometer at the Institute of Nuclear Science, University of Nairobi Kenya. The detector output is coupled to a pre-amplifier and thereafter electronically connected to a Canberra signal processing electronics and S100 Multi Channel Analyzer (MCA) inside a desktop personal computer (PC). The involved X-ray principles are well backed by documented knowledge in a period exceeding a century (Benka and Lubkini, 1995). Advancement in technology has also made X-ray spectrometer an indispensable tool in many research fields.

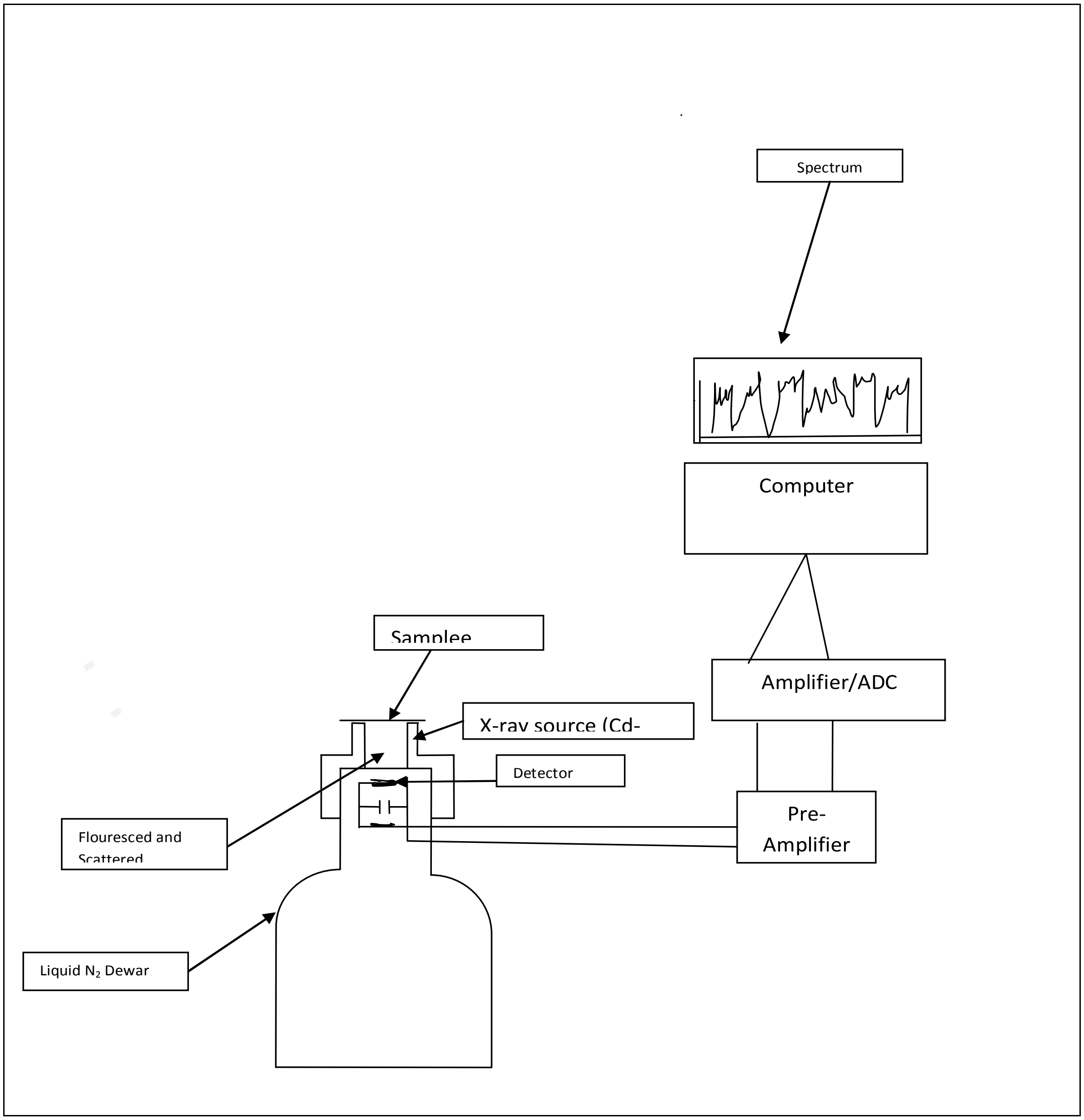



**Fig.3 The University of Nairobi EDXRF spectrometer setup used in analyzing Quartin clover and soil samples in this study**

This is well manifested in continued popularity of XRF application in environmental studies (Solomon *et al*., 2001).The shape of the peak is described by a Gaussian distribution used to describe the resolution parameter of the spectrometer in the spectrum model. Peaks distortion is due to Poisson statistics, where the observed photon counts (N) differ from the incident ($N_0$). Poisson distribution of the photon count is due to random nature of the incident photons that are then counted over a finite time period. The electronic noise is due to fluctuation in photon to charge carrier conversion and the electronic noise is mainly due to thermal energy production of charge carriers in the detector and the electronic circuits (Van Espan and Janssens, 1993). The following mineral micro-nutrients were determined from the soil sample and plant tissues using ERF spectroscopy described above in arrangement shown in Fig. 3.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Area of study

The Quartin clover was grown at the Faculty of Agriculture Field Station, University of Nairobi between February 2006 and July 2007. The station is ($1^0$ $15^1$ S and $34^0$ $44^1$ E), 12 Km North - West of Nairobi city (Jaetzold and Schimdit 1983). Average annual rainfall is approximately 1000mm bimodal distribution. The total rainfall is generally high in March – May period (long rain) than the November – December period (short rain). The two rainfall seasons are locally referred to as the "short" (mid- October to December) and "long" rain (mid – March to May). However on average in Kabete 57% of the annual rainfall is received in long rains and 43% in the short rains (Mburu, 1996).Soil pH 5.5


**Fig. 4 The experimental site as shown by the arrow was located at the University of Nairobi in Nairobi County on Latitude $1^0$ 15' South and Longitude $34^0$ 41'E**

### 3.2 Soil characteristics

Soil at Kabete is described as Humic Nitosols with kaolinitic clay minerals (Jaetzold and Schimdit, 1983). Other characteristics were presented on Table 3.1 shown below. The soil is well-drained, deep, dark reddish brown to dark red friable clay derived from Kabete trachyte. It responds to phosphate fertilizer but not to potassium (k) fertilizer because of the K supply from feldspar minerals in the parent material. Soil samples were collected in a "W" design at the experiment site before planting and taken to the laboratory for chemical analysis through X – Ray Florescence Spectroscopy. Soil samples from each terrain level were collected separately using soil auger and mixed in a large bucket. Two samples from each terrain level were put in paper bag, dried in a ventilated oven at 80 degrees centigrade for 72 hours. They were then homogenized, Compressed and analyzed for micro nutrient through EDXRF spectrometer (Fig 3) based on Cd109 radioisotope source for analysis of trace elements

**Table 3.1 Textural and chemical characteristics of Kabete experimental site**

| Depth (cm) | pH 1:2.5 | Total N% | P ppm | O.M % | % clay | %silt | %sand |
|---|---|---|---|---|---|---|---|
| 0-15 | 5.8 | 0.26 | 3.1 | 2.3 | 64 | 31 | 5 |
| 15-30 | 5.8 | 0.23 | 2.6 | 2.1 | 67 | 26 | 7 |
| 30-45 | 6.0 | 0.18 | 1.7 | 1.6 | 67 | 27 | 6 |
| 45-60 | 6.0 | 0.14 | 1.5 | 1.2 | 73 | 22 | 5 |
| 60-75 | 6.1 | 0.13 | 1.3 | 1.1 | 75 | 21 | 4 |
| 75-90 | 6.2 | 0.11 | 1.3 | 1.0 | 77 | 19 | 4 |

Source: Physical characteristics (Lenga,1979),chemical characteristics (Mburu, 1996)

Legend: pH- Potential hydrogen, %N- Total Nitrogen as a percentage, P -Phosphorous in parts per million OM% -Percentage Organic matter content

### 3.3 Experimental design and the establishment treatments

### 3.3.1 The field establishment treatment

Three experiments were conducted at Kabete campus field station. Field experiment carried out an uneven gradient between 2 and 15% slope. The field was disk ploughed and harrowed three weeks before planting. Plots of dimensions 3m x 3m with a 1m path all around the plots were demarcated using a meter ruler and sticks. Three guard rows of the Quartin clover were planted along the edges of the experimental site. The establishment treatments experiment was arranged in Randomized Complete Block Design (RCBD). The experiment site was in un- even gradient, thus it was divided into 3 slants namely: Upper, Middle, and lower slant terrain which were considered as a natural treatment. Four phosphate fertilizer levels were applied as treatments and replicated four times. The treatments were: O kg$P_20_5$/Ha, 30 kg/Ha $P_20_5$, 50 kg/Ha $P_20_5$ and 60 kg/Ha $P_20_5$. The design was chosen to test the effect of three land slant level locations and four fertilizer levels on herbage growth and the accumulation of mineral micronutrients in Quartin clover

Factors were: Local Terrain slants (upper, middle and lower slant), Sampling interval (2, 4, 6, and 8 week), and levels of Phosphate Fertilizer (60kg, 50kg, 30kg and 0kg $P_20_5$/ha )

Parameters were: Tissue mineral micronutrients concentration (Zinc, Iron, Iodine, Manganese, Copper, Cobalt, Selenium and Molybdenum), Herbage growth (plant height, ground cover leaf number, number of branches, days to flowering, dry matter, seed yield and Nodules formation. Potted plants were used to determine the root characteristic (nodule formation).

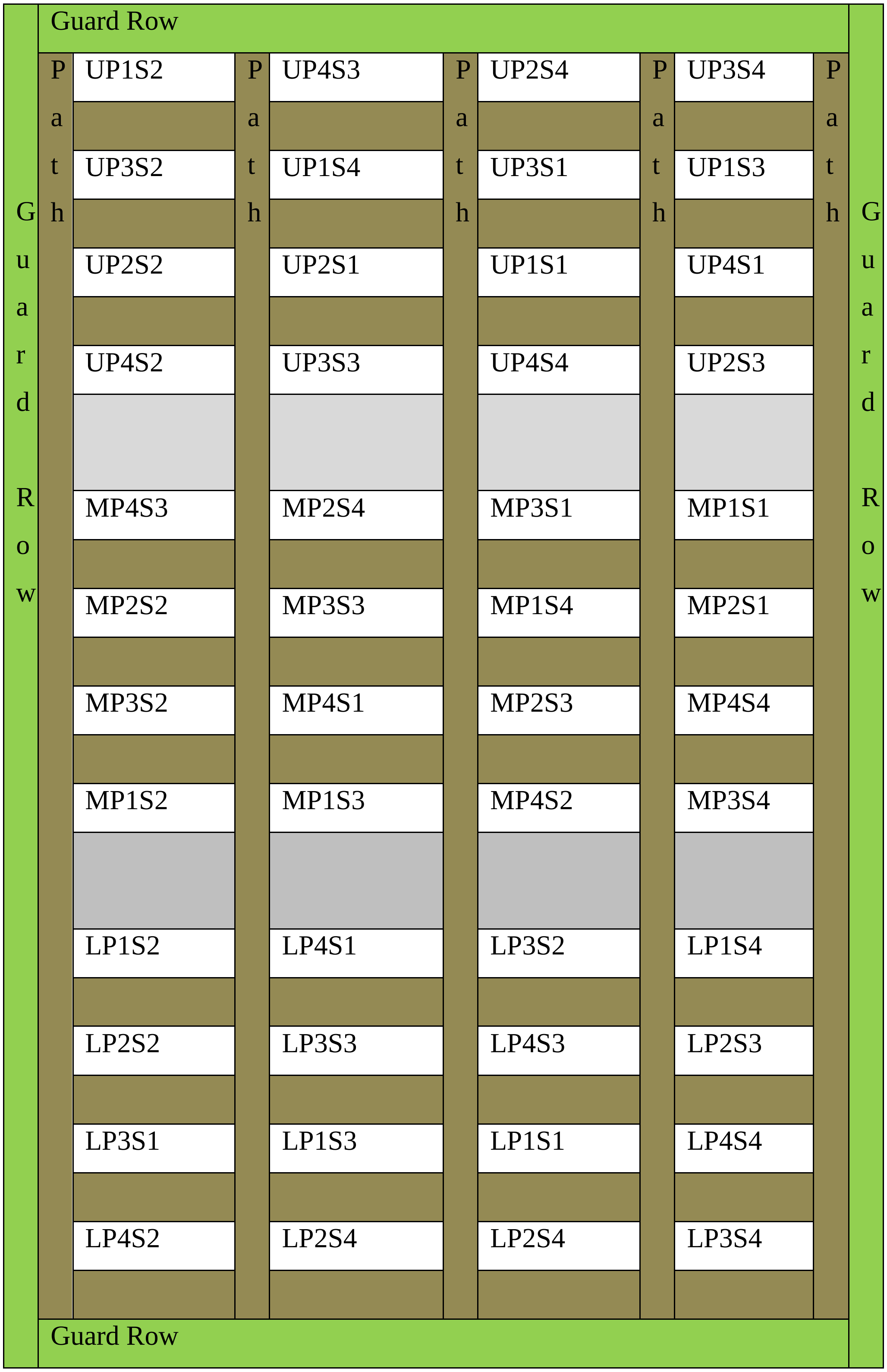



**Fig. 5a plot layout in the field experiment**

Legend: PI-P4 (Phosphate level at 0, 30, 50 and 60 kg/ha$^{-1}$ $P_20_5$ , )

SI-S4 (Sampling Interval at week 2, 4, 6, and 8)

U - Upper slant Terrain, M - Middle slant Terrain ,L- Lower slant Terrain

There were 16 plots of dimensions 9M$^2$ in each terrain level giving a total of 48 plots. Previously scarified Quartin clover seeds were drilled into shallow furrows 30cm apart and lightly covered with soil and pressed down with the sole of the foot to ensure seed-soil contact. The field experiment was set at the onset of the long rainy season. Top dressing with Calcium ammonium nitrate (CAN) was done after first weeding at 21 days after emergence at the rate of 30grams per row. Manual weeding with hand hoes was carried out twice before flowering and once after maturation. There were no pests and diseases infestation since the field was kept clean. Thinning was carried out to maintain the correct plant density (Fig. 6)

**Fig. 6 Photograph of researcher thinning plants to ensure correct plant density**

### 3.3.2 Open space Box establishment

The box establishment experiment was carried out in wooden boxes 1M$^2$. Soil that was put in boxes was collected from Kabete campus field station farm (previously planted with *Trifolium quartinianum* and *Vigna unguiliculata*) from three terrain levels namely; upper slant terrain (UST), middle slant terrain (MST), and lower slant terrain (LST). Triple super phosphate (46% $P_2O_5$) fertilizer was applied at 30 kg $P_20_5$ /ha. The soil and the fertilizer were mixed thoroughly and put into boxes. The boxes, twelve in number were laid in completely Randomized design (Fig. 5c).

| | | | |
|---|---|---|---|
| UST | MST | LST | UST |
| LST | UST | MST | LST |
| MST | LST | UST | MST |

**Fig 5b plot layout for box establishment experiment**

The box establishment experimental plots were watered manually with a watering can at least 5 day a week to ensure optimum soil moisture content. Top dressing with Calcium ammonium nitrate (CAN) was carried out after first weeding at 28 days after emergence at the rate of 10grams per row.

**3.3 3 Green house potting establishment**

The green house potting establishment was carried out in pots (polythene bags 6 inches high and 6 inches diameter). Soil that was put in pots was collected from Kabete campus field station farm (previously planted with *Trifolium quartinianum* and *Vigna unguiliculata*) from three terrain levels namely; upper slant terrain (UST), middle slant terrain (MST), and lower slant terrain (LST). Triple super phosphate (46% $P_2O_5$) fertilizer was applied at 30 kg/ha. $P_20_5$ The soil and the fertilizer were mixed thoroughly and put into pots 48 pots were laid in Randomized complete block design (Fig. 5c). The pots were placed in a green house and arranged in a Randomized Complete block design with three treatments (upper slant terrain, middle slant terrain and lower slant terrain soils) as illustrated in (Fig.5b)

| | | | |
|---|---|---|---|
| US1 | US4 | US2 | US3 |
| S3 | US1 | US3 | US1 |
| US2 | US2 | US1 | US4 |
| US4 | US3 | US4 | US2 |
| MS4 | MS2 | MS3 | MS1 |
| MS2 | MS3 | MS1 | MS2 |
| MS3 | MS4 | MS2 | MS4 |
| MS1 | MS1 | MS4 | MS3 |
| LS1 | LS4 | LS3 | LS1 |
| LS2 | LS3 | LS2 | LS2 |
| LS1 | LS4 | LS1 | LS4 |
| LS4 | LS2 | LS3 | LS3 |

**Fig. 5c plot layout for green house experiment to assess herbage growth**

The greenhouse potting establishment experimental plots were watered daily at least 5 day a week to ensure optimum soil moisture content. Top dressing with Calcium ammonium nitrate (CAN) was carried out after first weeding at 28 days after emergence at the rate of 2-3 grams per plant.

### 3.4 Soil and plant tissues sampling and analysis

#### 3.4.1 Field establishment soil sampling and analysis

Soil samples were collected randomly in a W shape from the three terrains levels of the farm at the experimental site previously planted with the Quartin clover and cowpea. The samples from each level were mixed together in a large bucket and two samples taken. They were analyzed for mineral micronutrients namely: Iodine, Iron, Cobalt, Copper, Zinc, Manganese, Molybdenum and Selenium using Energy Dispersive X-Ray Fluorescent (EDXRF) spectroscopy system at the Institute of Nuclear science and Technology (INST), University of Nairobi

### 3.4.2 Plant sampling and tissue analysis

Plant samples were cut at the base of the plant every two weeks for a period of eight weeks after emergence. The collected samples were oven dried at $72^0$C for three days and then ground into fine dust. The pellets were then irradiated by x-rays generated from Cd109 radioisotope source and the fluorescent x-ray were detected by a Si (Li) detector. The subsequent electrical signal generated in the detector is processed through the rest of the electronics of the EDXRF system at INST. The number of photons is related to the quantity of the element in the pellet from which mineral micronutrients density is then calculated.

### 3.4.3 Field establishment root sampling and analysis

Plant samples for root characteristics determination were collected from the potted plants. Individual potted plants in poly bags were submerged in water. The water was stirred gently to break soil clods to release the root and the nodules. The heavy soil particles settled at the bottom while the roots and organic debris were suspended in water. The process was repeated several times until all the roots were dislodged from the soil. The clean roots were air dried on trays, examined, and root nodules counted and their number recorded. Nodules were air dried and weighed. This exercise was repeated after every two weeks from emergence to 12 weeks of growth.

## 3.5 Sampling interval

### 3.5.1 Plant sampling for herbage growth determination

Plant sampling was carried out at two-week interval in all the three establishment experiments during the growing season. The herbage growth parameters were determined and data recorded each time.

### 3.5.2 Field establishment plant sampling for mineral micronutrient determination

Plant tissues were also sampled for determination of mineral micronutrients at various sampling intervals. The final plant sampling coincided with the cutback of Quartin clover at 50% flowering. Seeds were harvested manually cleaned and weighed for seed production and mineral micronutrients analysis.

### 3.6 Data Collection

#### 3.6.1 Data collection for laboratory germination test

Seeds were scarified and placed in a moist clothe in the laboratory. Germination count was carried out 10 days after sowing to determine the germination percentage.

#### 3.6.2 Data collection in box establishment

Emergence: Seeds were scarified and planted in box establishment experimental plots. Emergence counts were conducted at day 10 after sowing and the numbers of emerged seedlings were recorded.

Plant height: Plant height was measured in ten (10) plants per plot every 14 days by placing a ruler from the ground to the topmost part of the plant and data was recorded Comparison was made between the phonological stages.

Plant cover: Plant cover was determined by monitoring canopy development non-destructively using a visual rating scale based on the percentage of ground cover (area per stand) at $2^{nd}$ - $12^{th}$ weeks after planting at specific growth stages.

Leaf number: Leaf number was determined by counting the number of leaves per plant. It was used to compute the number of leaves per hectare and the rate of leaf formation. Data was collected two weeks after emergence and after every 14 days until 50% flowering.
Branching: Primary branches were counted every 14 days from emergence to $12^{th}$ week of growth and the rate of branching determined.

Flowering: The days to first flowering were determined by counting the number of days after emergence to the first appearing of floral primordial, and to 50% flowering, the number of inflorescence per plant was determined. This gave an indication of how long the legume takes to flower, as this is the most important criterion for identifying suitable time for harvesting the forage.

### 3.6.3 Data collection in green house experiment

Emergence: Seeds were scarified and planted in potting establishment experimental plots. Emergence counts were conducted at day 10 after sowing and the numbers of emerged seedlings were recorded.

Plant height: Plant height was measured in ten (10) plants per plot every 14 days by placing a ruler from the ground to the topmost part of the plant and data was recorded Comparison was made between the phonological stages.

Plant cover: Plant cover was determined by monitoring canopy development non-destructively using a visual rating scale based on the percentage of ground cover (area per stand) at $2^{nd}$ - $12^{th}$ weeks after planting at specific growth stages.

Leaf number: Leaf number was determined by counting the number of leaves per plant. It was used to compute the number of leaves per hectare and the rate of leaf formation. Data was collected two weeks after emergence and after every 14 days until 50% flowering.

Branching: Primary branches were counted every 14 days from emergence to $12^{th}$ week of growth and the rate of branching determined.

Flowering: The days to first flowering were determined by counting the number of days after emergence to the first appearing of floral primordial, and to 50% flowering, the number of inflorescence per plant was determined. This gave an indication of how long the legume takes to flower, as this is the most important criterion for identifying suitable time for harvesting the forage.

### 3.6.4 Data collection for field establishment

Emergence Seeds were scarified and planted in field establishment experimental plots. Emergence counts were conducted at day 10 after sowing and the numbers of emerged seedlings were recorded.

Plant height: Plant height was measured in ten (10) plants per plot every 14 days by placing a ruler from the ground to the topmost part of the plant and data was recorded **(Fig. 7). Comparison was made between the phonological stages**.

**Fig. 7 Photograph of the researcher** **Fig. 8 Photo of dried roots for nodules count**

measuring and recording plant height

Plant cover: Plant cover was determined by monitoring canopy development non-destructively using a visual rating scale based on the percentage of ground cover (area per stand) at 2nd - 12th weeks after planting at specific growth stages.

**Table 3.2 Visual rating scale for percentage ground cover**

| Scale | % ground cover |
|---|---|
| 1 | $\leq$20 |
| 3 | 20-40 |
| 5 | 41-60 |
| 7 | 61-80 |
| 9 | 81-100 |

Leaf number: Leaf number was determined by counting the number of leaves per plant. It was used to compute the number of leaves per hectare and the rate of leaf formation. Data was collected two weeks after emergence and after every 14 days until 50% flowering.

Branching: Primary branches were counted every 14 days from emergence to 12$^{th}$ week of growth and the rate of branching determined.

Flowering: Days to first flowering were determined by counting the number of days after emergence to the first appearing of floral primordial, and to 50% flowering, the number of inflorescence per plant was determined. It gave an indication of how long the legume takes to flower, since it is the most important criterion for identifying suitable time for harvesting forage.

Roots from potted plants were dipped in water several times until all the soil was dislodged from the roots. They were dried under shade (Fig 8). Root nodules were counted and recorded

### 3.7 Dry matter yield and tissue analysis

Aerial dry matter was determined at 120 days after planting in all the three establishments. Plant samples were cut at 5 cm stubble height above the ground. Fresh weight was measured immediately after cutting and then the samples were dried in a ventilated oven at 70$^{0}$c for 72 hours to a constant dry weight yield, for dry matter determination.

Seeds were harvested manually and threshed at the end of the season and then data recorded for seed yield determination. Clean seeds were weighed and the weight recorded. Seed for mineral micronutrients analysis were crushed in to a fine powder, pelletized and then analyzed for mineral micro nutrients through EDXRF system.

### 3.8 Data Analysis

Data collected was subjected to descriptive analysis and analysis of variance (ANOVA) and mean separated using the least significant difference of means using SPSS Vol.11.5 package.

**CHAPTER FOUR**

# EFFECTS OF WEATHER ON THE PERFORMANCE OF QUARTIN CLOVER AT KABETE, KENYA

## 4.1 Introduction

The phenological stages in African annual clover can be divided into four growth stages (Muthoni, 2000). These four stages of growth are evident in Quartin clover. They are hereby described as first growth stage (seedling stage), 2nd growth stages rapid vegetative growth stage), 3rd growth stage (maturation stage), and 4th growth stage or senescent stage and death. Weather conditions were observed and recorded from University of Nairobi Kabete campus field station. The effects of the weather conditions on the growth and development of Quartin clover were assessed and the following information was generated.

## 4.2 Methodology

Data for Weather conditions collected daily throughout the growing Season from Kabete Campus weather station located at Upper Kabete Campus field station. One decade weather condition means were also recoded for comparisons. Quartin clover growth and development stages were observed and recorded in Table 4.1. Excess rainfall was disposed as surface runoff infiltration or evapo-transpiration. The soil moisture content determines the availability of moisture to plants needed for growth and development. The soil moisture content was determined through the gravimetric method.

## 4.3 Results

### 4.3.1 Sampling Intervals

Field observations on growth and development were made every fourteen days from emergence to senescence and data was collected and recorded. Sampling intervals (SI) as a factor of production were grouped in a block of periods and are coded SI 1 - SI 12 as shown in Table 4.1.

**Table 4.1 Growth stages based on sampling intervals (SI)**

| Sampling interval | Interval duration | | | Response |
|---|---|---|---|---|
| | Days | Weeks | Months | Growth stage |
| SI 1 | 14 | 2 | 0.5 | 1-Seedling stage |
| SI 2 | 28 | 4 | 1.0 | |
| SI 3 | 42 | 6 | 1.5 | |
| SI 4 | 56 | 8 | 2.0 | 2-Active vegetative |
| SI 5 | 70 | 10 | 2.5 | growth stage |
| SI 6 | 84 | 12 | 3.0 | |
| SI 7 | 98 | 14 | 3.5 | 3-Mature growth stage |
| SI 8 | 112 | 16 | 4.0 | |
| SI 9 | 126 | 18 | 4.5 | 4-Senescent stage and |
| SI 10 | 140 | 20 | 5.0 | |
| SI 11 | 154 | 22 | 5.5 | Death |
| SI 12 | 168 | 24 | 6.0 | |

**Findings**

During seedling stage, the growth was slow. This slow growth could be due to few and small leaves causing photosynthesis to be slow. The roots at this stage are not well established hence limiting the uptake of water and nutrients. This stage went on from emergence to 45 days after emergence (SI 1 – SI 3). The second stage was between 45 and 90 days, which were indicated by active vegetative growth. It was characterized by rapid increase in plant cover, height and branching. This could have been because roots were more established, leaves were more and active in photosynthesis and the roots had developed rapidly to take up nutrients and water. Root nodules had fully developed hence fixing free nitrogen for the plant. The rapid growth stage (SI 4 – SI 6) ended around flowering time. The maturity stage (SI 7 and SI 8) was indicated by maximum growth; plants attained maximum height and branching. All plots had attained 100% plant cover. The early maturation stage was characterized by flowering and seed formation (seed set). Weather conditions especially rainfall, number of rainy days and soil moisture stress has adverse effect on the plants growing in the open field. Fourth stage or simply post flowering stage (120 days and above) represented as Sampling Interval 9 – Sampling Interval 12) was a slow development phase, seeds were formed, inflorescent dried, cover and leave number declined while the plants fell over to form a mate. These growth stage of Quartin clover conformed to the growth cycle of annual crops (Muthoni, 2000).

### 4.3.2 Weather conditions at the experimental site.

Rainfall data was collected from Kabete Campus field station, weather station and recorded in Tables 4.2. Nothing that environmental conditions (ecological) appear to be significant determinants for the successful determinant of Quartin clover (Akundabweni personal communication), the weather conditions at Kabete field station was carefully examined. Total rainfall during the study period between January, 2006 and March 2007 (Fig 9b) was generally higher than decade mean for the month of January, April and October 2006 and January and February 2007 (fig 9b) based on a decade mean total rainfall for long rain peak was highest April unlike short rains peaked in November 2006. The decade mean was higher than total rainfall outside the two peaks. The year of study was lower than normal (fig 9b). Plants in the field trials received low rainfall during seedling, reproductive and early maturation stage. Late maturation and senescent stage received high rainfall, which caused some plants to regenerate and continue flowering. Quartin clover behaves this way as shown in previous studies (Akundabweni, 1984)

The number of rainy days were highest in the month of April (Fig 9b) compared to the decade mean. There were also more rainy days in the month of September October and November 2006 compared to the decade mean. The rest of the months during the growing period had relatively fewer rainy days except February and June 2006 which had equal number of rainy days compared to those of decade mean for the same months (Fig. 9b).

At low altitude, daytime mean temperatures tend to be high for all the year round. Average air temperature for Kabete during the study period was higher than the decade mean (Fig. 11). However for the months of April and September of the field study year,

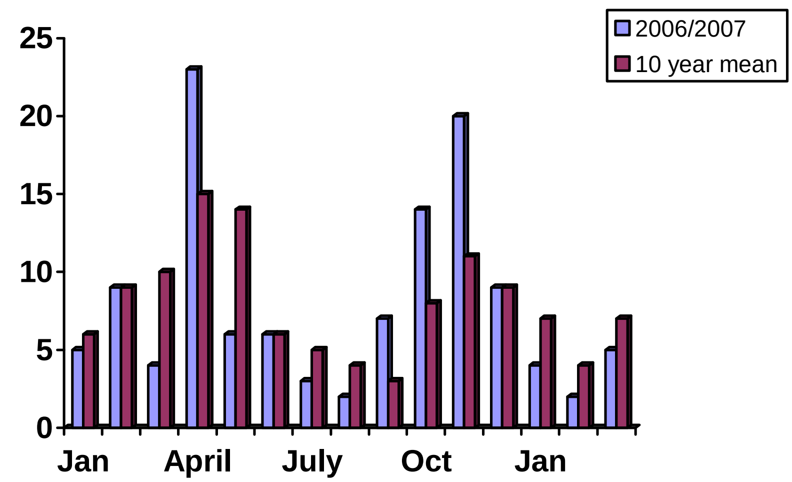
air temperature was lower than that of 10 year mean. Temperature influences the rate of plant growth and development processes (Desbeiz *et al*., 2004). The high daytime temperatures caused Quartin clover develop very fast in Box plots since they were supplied with adequate water through can irrigation unlike field plots that depended on rainfall.
The monthly daily maximum, minimum, and mean air temperature for Kabete during the growing period are presented in Table 4.3. The month of February 2007 was the hottest with an average air temperature of 27.6$^{0}$C

Relative humidity (RH) is the ratio of actual vapour to saturation vapour pressure at the same temperature. The monthly mean percentage RH was recorded at 00600 and 01200hrs. Results are as presented in Table 4.4. The percentage RH was generally low during the day but might have risen in the evening and remained between 60 to 80% until the next morning. Dew resting on leaves, stem and shoot might have been an important source of moisture for plants. The RH was highest in the month of April 2006 during the peak rains and lowest in February 2007 during the drought period.

**Findings**

The total rainfall during the study year was 922.34mm for Season 1 and 489.01 for Season 2. In Season 1, there were 12 days with rainfall greater than 25mm and a total of 25 days when rainfall was higher than 10mm (Fig. 9b). The highest amount received on any one day was 129mm in January 2006. For five months between February and August, rainfall received was less than 5mm of rainfall per day. On average basis, only April had an average more than 10mm per day. The highest total rainfall in Season 2 was 118.3mm in November received in less than three weeks which corresponded with rapid growth.

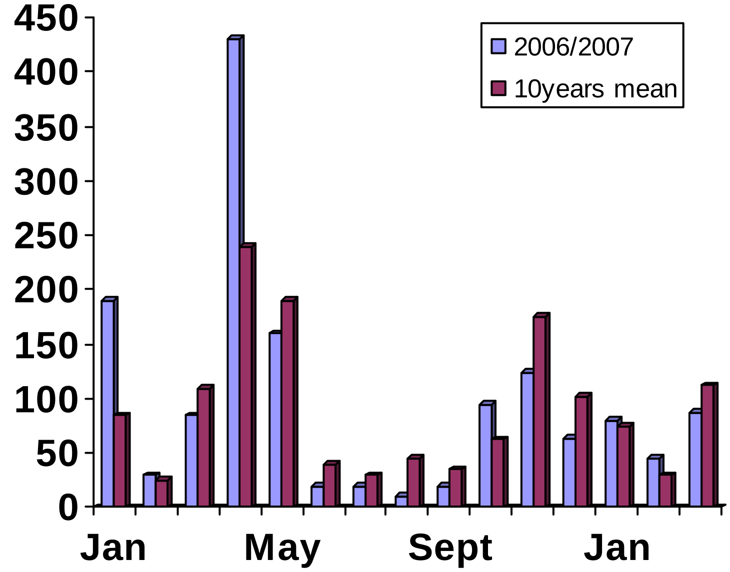
No. of rainy days




Time in months

**Fig. 9a) Number of rainy days at the experimental site compared to 10 year mean**

**Rainfall(mm)**




Time in months

**Fig.9b Total monthly rainfall (mm) at the experimental site for the long and short rain season 2006/2007 compared to 10 year mean**

April and September had the highest rainfall peaks and favoured growth and development of Quartin clover. Total evaporation in Season 1 was 101.2mm in July 2006. Total evaporation was very high ranging from 113.4 - 174mm in season 2 stressing the crop. Season 2 had a short dry spell in September and a prolonged dry spell from December, 2006 to March. Long rains were well distributed through out the Season which lead to low seeds production. Long rainfall duration appeared to have enhanced adequate moisture in the air and promoted establishment, growth and maturity of the clover.

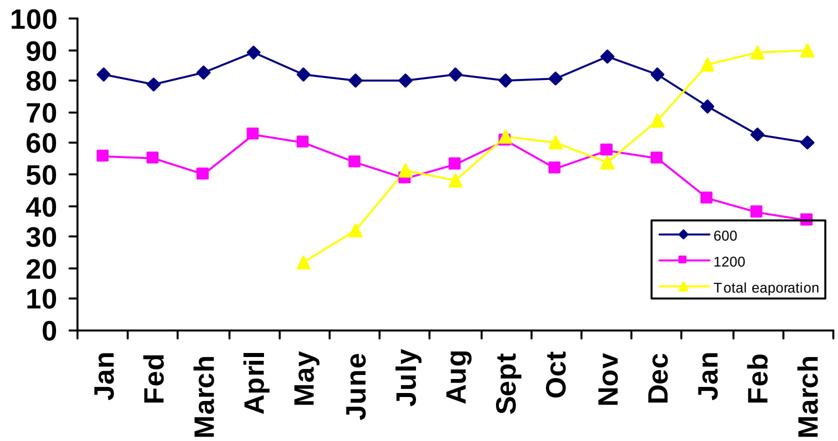



**Fig. 10 Relative humidity (00600 and 01200 hrs) and total evaporation at the experimental site during the study period (2006/20070**

Season 2 suffered two drought periods (Fig 9b) which affected the growth of the clover as indicated by the results on DM and seed production in the field trial. Due to changing climate conditions, September/October as a calendar time appears to be irrelevant in timing of planting. Poor timing can lead to total crop-seed failure; such as was experienced in Quartin clover planted in November, 1998 which was followed by heavy down pour in the following year at flowering. Inflorescences as a result were destroyed and no seed was harvested (Akundabweni Personal communication).

Average air temperature during the study period was higher than the decade mean for all the months except April and September. Generally temperatures are lower in May, July and August periods compared to the other periods of the year at Kabete. There seemed to be a rainfall temperature interaction in the growth of Quartin clover since the crop planted in September and supplied with optimum soil moisture through a watering can, yielded higher than the one planted in February when the mean monthly temperature at maturation stage was between 18.3 $^{0}$C to 25.2 $^{0}$C and 20.6 $^{0}$C to 27.6 $^{0}$C respectively. This could have agronomic implications with respect to time of planting for most regumes (McWilliams, 1978). This could be evaluated further as several scenarios pointed above indicated that the best time of planting of Quartin clover is yet to be established. Kayinde, (2000) had suggested that the early year planting of Quartin clover in the warmer Jan-June favored a high seed production than the cooler mid-year July - December planting.

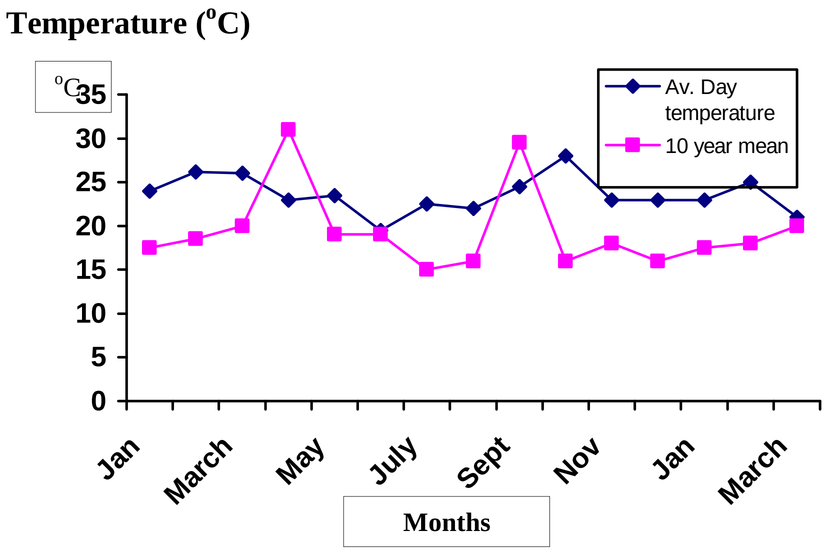



**Fig. 11 Average air temperature ($^{o}$C) at the experimental site (Jan/2006-Mar/2007) compared to 10 year mean**

### 4.3.3 Water content of the soil.

The gravimetric method for the determination of percentage soil water content was used to determine the amount of water in the sampled soil according to results presented in Table 5.2 The highest soil moisture content (33.58%) was attained in November in the lower slant terrain and the lowest percentage soil moisture content was (15.62 %) was the upper slope terrain in the month of January, giving a range of 17.96 units. Some plants wilted occasionally while other plants died during periods of moisture stress (drought) especially in the upper and some patches in the middle slope terrain. The trend in percentage moisture content is shown in (Fig. 12) corresponded with increase in herbage growth.

**Findings**

Soil water content was measured gravimetrically from 0 to 30cm depth in the field experiment throughout the growing season (Table 4.5) Any changes in percentage water content during the rain free periods were assumed to be due to evapo-transpiration, i.e. evaporation from the soil surface and water uptake by roots and subsequent loss from the leaves. The longest dry periods were September, December and February example of water depletion patterns are shown in Fig 5. October 2006 and January 2007 had the lowest percent soil water content of about 15% both in upper and middle slant terrain. That of the lower slant terrain did not fall below 20%. The month of November 2006 and April 2007 had the highest percent soil water content for all the three land partitions. However the lower slant terrain had the highest moisture content in those two months (33.58%). The highest range in percent soil water content throughout the growing Season was 18.61 in the upper slant terrain (Table 4.5). This fluctuation in soil moisture content adversely affected plants in the upper and middle slant terrain causing some of them to wilt or die. This is because water is a major constituent of plant tissue, a solvent in which solutes including mineral nutrients are transported, reactant in processes like photosynthesis and hydrolysis, is important in maintenance of turgidity and regulation of leaf temperature (Debeiz *et al*., 2004). On a worldwide scale water is the most important factor-limiting crop yield. Crop productivity is generally has been expressed on the basis of dry matter produced per unit water evaporated from a unit of land area. Thus the productivity depends on the partitioning of water inputs between unproductive losses of water (i.e. through direct evaporation, surface run off, drainage and uptake by weeds) and water used for dry matter production i.e. transpiration) in a cropping system when supplies are adequate, nutrition is commonly the most limiting.

The differences in the dry matter production are attributed to soil fertility and water availability among the land partitions. The results suggest a water fertility interaction in the growth and development of annual African clover. The crop in the upper slant terrain experienced severe water deficits in the dry periods. Some sections of the middle slant terrain also experienced the drought but those in the lower slant did not experience such water deficits in the upper and middle slant terrain especially in the wet periods. Surplus water drained as surface runoff carrying fertile soil to the lower parts in the lower part of the farm where water drained into deep percolation and/or surface runoff. For other systems excess water will go into deep percolation (Kironchi, 1992) and thus feed river and ground water.

When the amount of precipitation in a locality is insufficient, crop growth is reduced since soil may not respond to fertilizer addition if native fertility is adequate to produce the crop yield permitted by the moisture regime (Akundabweni *et al*., 1991). The highest moisture content in the soil was attained in the month of November i.e. 33.58%, 31.03% and 30.78% for the lower, middle and upper slant terrain respectively. These regimes corresponded with the successful late seedling stage (stage I) and early active vegetative growth stage (stage 2). However the moisture content dropped drastically between the month of November and January adversely affecting the growth and development of clover. Plant height was grossly affected in the field and was only a third of the average height of clover plant.

Many plants in the upper and middle slant terrain were wilting during daytime and regained their turgidity in the evening and at night. A number of them wilted permanently and died during the drought periods. Differences in soil water content among the land partitions (terrain levels) were more pronounced soon after rainfall with the upper slant having the highest level between December and January 2006/2007. During this period, there were two lowest peaks of percent water contents; one in January (15.02%) and February (17.6%) both in the upper slant terrain.

The Seasonal pattern of moisture availability in the soil for plant evapo-transpiration is also important particularly where rain fall over a very limited period in the year. The pattern of moisture availability has great significance because it determines the severity of the principle constraint on agriculture. Mean rainfall may be a poor guide to reliability of moisture availability as many areas experience more years with annual rainfall less than the long term mean than with rainfall above it (Mburu, 1996.)

Wilting of plants under field condition did not depend only on soil moisture suction but also on the potential evapo-transpiration, the ability of the plants root to ramify into the soil (depending on growth stages) because wilting was observed during seedling stage and maturation stage. However, wilting does not occur at a fixed soil moisture sanction for different growth stages and for different plant types but over a range of percent moisture content.

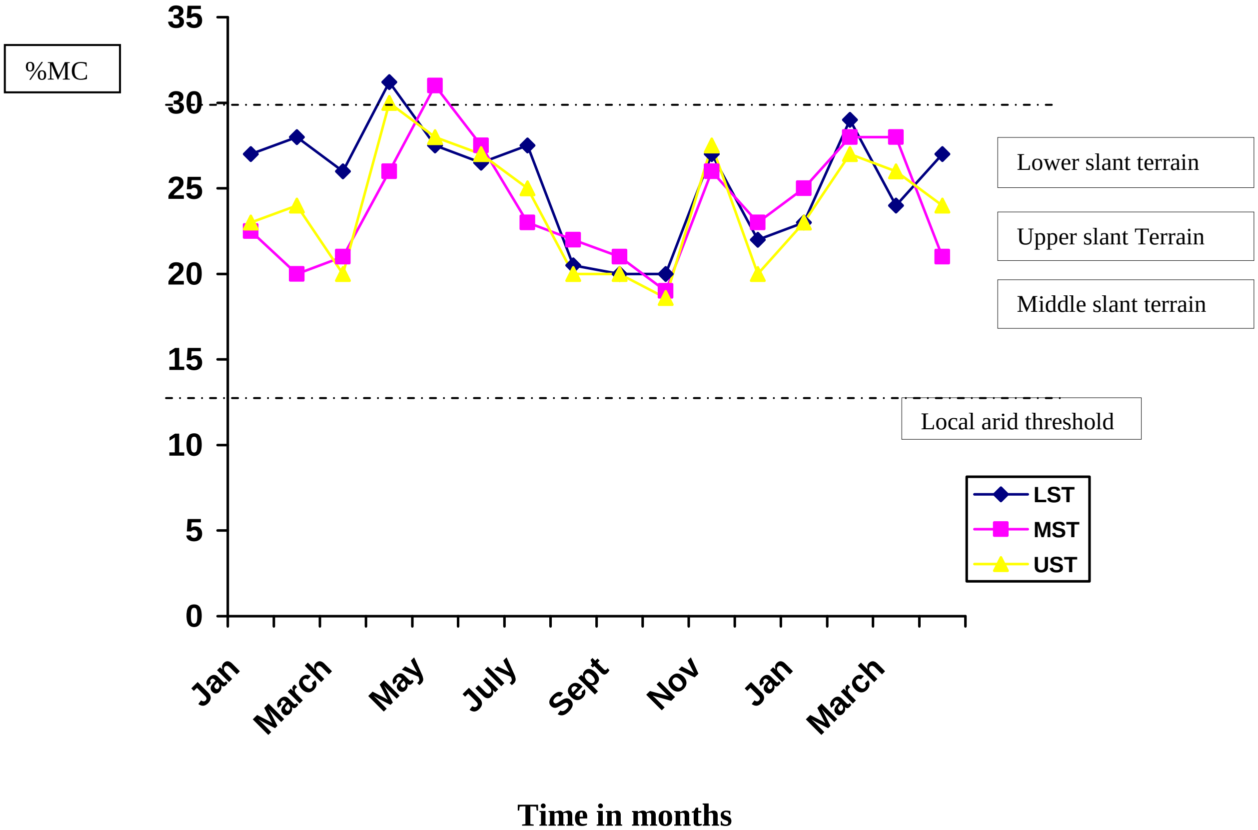



**Fig. 12. Changes in soil moisture content at 30cm depth determined using gravimetric method of soil moisture determination between January, 2006 and March 2007.**

Legend: LST: Lower slant terrain, MST: Middle slant terrain, UST: Upper slant terrain

%MC: Percent moisture content. Levels 0% to 19% is aridity zone that can hardly support a crop

### 4.3.4 Conclusions

1. The growth stage of Quartin clover conformed to the growth cycle of annual crops from germination to senescence.
2. Temperature influenced the rate of plant growth and development processes. This was demonstrated by the difference in plant height between the green house experiment and the field experiment
3. Long rainfall duration enhanced adequate moisture in the air and in the soil and promoted establishment, growth and maturity of the clover.
4. The productivity depended on the partitioning of water inputs between unproductive losses of water (i.e. through direct evaporation, surface run off, drainage and uptake by weeds) and water used for dry matter production i.e. transpiration) in a cropping system when supplies are adequate, nutrition is commonly the most limiting.
5. Mean rainfall might be a poor guide to reliability of moisture availability as many areas experience more years with annual rainfall less than the long term mean than with rainfall above it.

# CHAPTER FIVE

# MORPHOLOGICAL GROWTH AND DEVELOPMENT OF QUARTIN CLOVER UNDER DIFFERENT CULTURAL CONDITIONS AT KABETE

## 5 .1 Introduction

Annual forage legumes are recognized by their potential to produce extra and high protein feed from fallow land. These species are planted and harvested in a single year and can be used to for grazing, harvested for hay or harvested for grains and straw at maturity. Trifolium species can be incorporated in convectional farming beside their value as high quality animal feed. Quartin clover can be planted in highlands areas for feed production, and soil and water conservation. African annual clovers have now extensively, been documented to possess excellent, foraging potential for livestock (Kahurananga *et al*., 1986). They thrive well on long duration retained soil moisture, which is a characteristic of heavier bottomland soils (Akundabweni *et al.,* 1991).

The soil interplay of the physiochemical factors is likely to be of crucial importance in the natural selection of African clover, the adaptation performance, the ultimate yield and forage quality. Soil condition and climate are factors that influence not only growth but also subsequent dry matter yield accumulation and nutritive quality of clover (Kahurananga *et al*., 1984). Akundabweni, (1984) however, observed that some soils, which rapidly lose water tend to succumb to drought more quickly than slow water losing soils. In his experiment he found that the set of loose soil did poorly in biomass accumulation compared heavier soils.

## 5.2 Methodology

Seeds were scarified using a sand paper and a hard service. They were then drilled into the soil in field plot, 1m x1m boxes and green house pots. The box plots were watered at least 5 days in a week to ensure optimum soil moisture. The plots were observed for seed emergence. The results were presented in Table 4.6. Plant height from the base of the plant to the upper most tip of the plant was measured after every two weeks and result recorded. Branches were counted and recorded. The rate at which plant cover developed was observed and recorded against a scale of 1-9. The number of leaves from the sample plants were counted and recorded. Potted plants were used to in nodule determination.

The paper bags were torn and the sample dipped into water in a bucket several times until all the clods were dislodged. The roots were dried under shade and the number of nodules counted and recorded. When the plants were fully grown and seeds developed, they were cut at the base, dried at 72$^{o}$C for 72 hours and weighed for dry matter determination.

## 5.3 Results

### 5.3.1 Field establishment

Seed Emergence

The results showed that seeds germinated and emerged uniformly after 7-10 days of sowing. Mean percent seed germination was determined and the result recorded in the table 4.6 below.

**Table 4.6 Percent emergence count for seed viability trail for the year 2006/2007.**

| Treatment | Field Trial | Boxes Trial | Greenhouse (potted plants) |
|---|---|---|---|
| UST | 82.1% | 85.4% | 87.8 % |
| MST | 84.9% | 87.6% | 88.4 % |
| LST | 85.3% | 87.9% | 90.7 % |

Laboratory (paper/germination) 91.6%

Plant Height

Plant height increased as growth stages increased taking a form of sigmoid curve in all the three slant treatments. The highest height attained by the plants was 52.8cm. The average plant height was 46.49 cm, 45.93 cm, and 44.56 cm in the lower, middle and upper slant terrain respectively. The internodes for both the main stem and the lateral branches were short and the leaves were compact due to moisture stress.

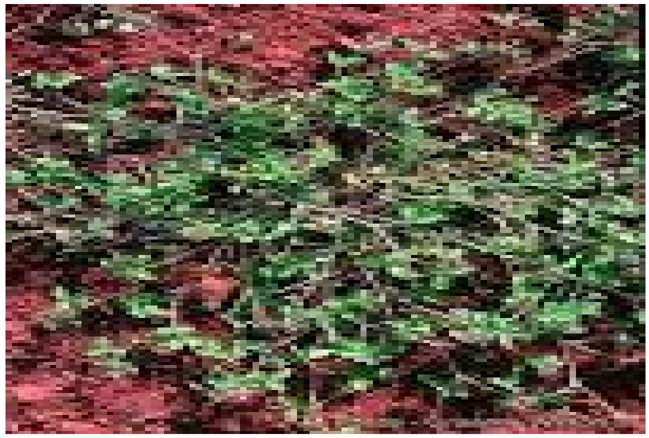


**Fig. 13 Photograph of a moisture stressed Quartin clover in the field experiment middle slant.**

Number of leaves

The number of leaves per plant increased rapidly during the vegetative growth stage, and then more slowly or decreased. The average number of leaves per plant at the end of the vegetative phase was 171, 167, and 232 in the upper slant terrain, middle slant terrain and lower slant terrain respectively. The lower slant terrain had the plant with the highest number of leaves though they were smaller in size. The total number of leaves per plant decreased at senescence stage.

Number of primary branches

The number of main stem nodes and branches per plant increased as days after planting increased. Branching occurred after the appearance of the third trifoliate leaf on the main stem node close to the cotyledon leaves and progressed bilaterally. The average number of main stem branches was 6.50, 6.17, and 5.57 in the lower, middle and upper slant terrain respectively.

Percent ground cover (as indicated by WHO growth rating)

Plant cover trends on the overall almost followed a sigmoid pattern. Number 1-9 are used here only as index. Increased plant cover occurred in the early stage of growth (between Stage 1- Stage 6). A plateau occurred in stage 3 and 4, a period at which plant cover was maximum. There after a decline was experienced in the $4^{th}$ stage of growth.

Nodules formation

There was no evidence of nodule formation in the first two weeks after emergence of the seedlings. However response of nodules to diammonium Phosphate application became apparent in the fourth week and increased steadily to eight week (Appendix 10). Fertilizer application had significantly ($P \leq 0.05$) different effect compared to those plants with 0 level of $P_20_5$

Seed Production.

Average seed yields were 0.507, 0.466 and 0.454 tons $ha^{-1}$ in the lower middle and upper slant terrain respectively. Seed yields were affected adversely by soil moisture stress during seasonal drought at maturation stage.

Dry matter production

The above ground dry matter yield at 50 % flowering was determined and recorded for dry matter analysis. Plant cover increased rapidly in during the rapid vegetative growth period. The average dry weight of plants was 11.80, 10.23, and 8.53 tons per hectare for the lower, middle and upper slant terrain respectively.

### 5.3.2 Open space box establishment

Seed Emergence

The results showed that seeds germinated and emerged uniformly after 7-10 days of sowing. Mean percent seed germination was determined and the result recorded in the table 4.6

Plant Height

Plant height increased as growth stages increased taking a form of sigmoid curve in all the three slant treatments. The highest height attained by the plants was 57.3cm. The average plant height was 49.69 cm, 49.13 cm, and 47.76 cm in the lower, middle and upper slant terrain respectively.

Number of leaves

The number of leaves per plant increased rapidly during the vegetative growth stage, and then more slowly or decreased. The average number of leaves per plant at the end of the vegetative phase was 209, 205, and 212 in the upper, middle, and lower slant terrain treatments respectively. The lower slant terrain had the plant with the highest number of leaves though they were smaller in size. The total number of leaves per plant decreased at senescence stage.

Number of primary branches

The number of main stem nodes and branches per plant increased gradually from emergence to senescence. Branching occurred after the appearance of the third trifoliate leaf on the main stem node close to the cotyledon leaves and progressed bilaterally. The average number of main stem branches was 13, 12, and 9 in the lower, middle and upper slant terrain respectively.

Percent ground cover

Quartin clover emerged from the soil 7 to 10 days after sowing. Increased plant cover occurred in the early stage of growth (between Stage 1- Stage 6). Number 1-9 were used only as an index for plant cover given by the World Food Programme. Plant cover was maximum at stage 3 and 4of growth and development

Seed yield.

Average seed yields were 0.610, 0.572 and 0.546 tons $ha^{-1}$ in the lower middle and upper slant terrain respectively. Seed yields were affected adversely by soil moisture stress during seasonal drought at maturation stage. Box establishment experiment (Fig.14) showed the best performance in mean seed yield in tons per hectare

**Fig. 14: Photograph of well set inflorescence and seed setting in the box plots**

Dry matter production

The above ground dry matter yield at 50 % flowering (120 day) was measured and recorded for dry matter analysis. Early period of increased plant cover occurred in the first half of its overall growth between SI 2 and SI 6 as reflected by the ground cover. The average dry weight of plants was 12.20, 11.83, and 11.64 tons per hectare for the lower, middle and upper slant terrain respectively.

**5.3.3 Green house potting establishment**

Seed Emergence

The results showed that seeds germinated and emerged uniformly after 7-10 days of sowing. Mean percent seed emergence was determined and the result recorded in the table 4.6

Plant Height

Plant height increased as growth stages increased taking a form of sigmoid curve in all the three slant treatments. The highest height attained by the plants was 47.97cm. The average plant height was 48.52 cm, 47.94 cm, and 47.38 cm in the lower, middle and upper slant terrain respectively.

Number of leaves

The number of leaves per plant increased rapidly during the vegetative growth stage, and then more slowly or decreased. The average number of leaves per plant at the end of the vegetative phase was 194, 187, and 228 in the upper, middle, and lower slant terrain treatments respectively. The lower slant terrain had the plant with the highest number of leaves though they were smaller in size. The total number of leaves per plant decreased at senescence stage.

Number of primary branches

The number of main stem nodes and branches per plant increased gradually from emergence to senescence. Branching occurred after the appearance of the third trifoliate leaf on the main stem node close to the cotyledon leaves and progressed bilaterally. The average number of main stem branches was 13.2, 12 8, and 12.4 in the lower, middle and upper slant terrain respectively.

Percent ground cover

Quartin clover emerged from the soil 7 to 10 days after sowing. Increased plant cover occurred in the early stage of growth (between Stage 1- Stage 6). Number 1-9 were used only as an index for plant cover given by the World Food Programme. Plant cover was maximum at stage 3 and 4of growth and development

Seed yield.

Average seed yields were 0.522, 0.572 and 0.562 tons $ha^{-1}$ in the lower middle and upper slant terrain respectively. Seed yields were affected adversely by soil moisture stress during seasonal drought at maturation stage.

Dry matter production

The above ground dry matter yield at 50 % flowering (120 day) was measured and recorded for dry matter analysis. Early period of increased plant cover occurred in the first half of its overall growth between SI 2 and SI 6 as reflected by the ground cover.

The average dry weight of plants was 11.94, 11.12, and 11.05 tons per hectare for the lower, middle and upper slant terrain respectively.

## 5.4 Findings

For successful seed germination and plant establishment, the soil must be sufficiently moist. Moisture ensured adequate opportunity for water uptake by germinating seeds and water loss from the germinating seed should not be excessive. Researchers recommend that there in need for soil seed contact to assist moisture movement from the soil to the seed and that is why seedbeds should be fine and firm. In this study the seedbed were pressed down with the sole of the foot to ensure this contact because as seed/soil contact become poorer, the rate of water absorption by the seed and the rate of seed germination become slower.

Under Kabete conditions, seedlings emergence occurred within 10days after sowing scarified Quartin clovers seed. Hard seed coat is an adaptive feature in legumes, which in nature prevent the possible loss of all sown seeds if one germination event is followed by adverse conditions in areas of unreliable rainfall. (Boonman, 1977) germination could be delayed by the impermeability of the seed coat. Dormancy caused by hard seed coat must be broken if germination and establishment are to be rapid and uniform. Differences observed between seed emergence in green house, box establishments and plant field establishment were mainly due to water stress in the field estanlishment. For this reason, it is not good to practice dry seeding at Kabete in clover, if maximum establishment is to be expected.

The emergence percent was highest in the laboratory condition compared to other establishments. The choice of sowing rate is determined by such factors as number of seeds per kilogram, seed quality, level of seed-bed preparation, slope, climatic risks, growth habit and the extent of weed problem. High seed rate is not necessary for clovers as they will thicken up quickly from their fillers and lateral branches ensuring quick ground cover, hence reducing the risk of soil erosion and weed competition.

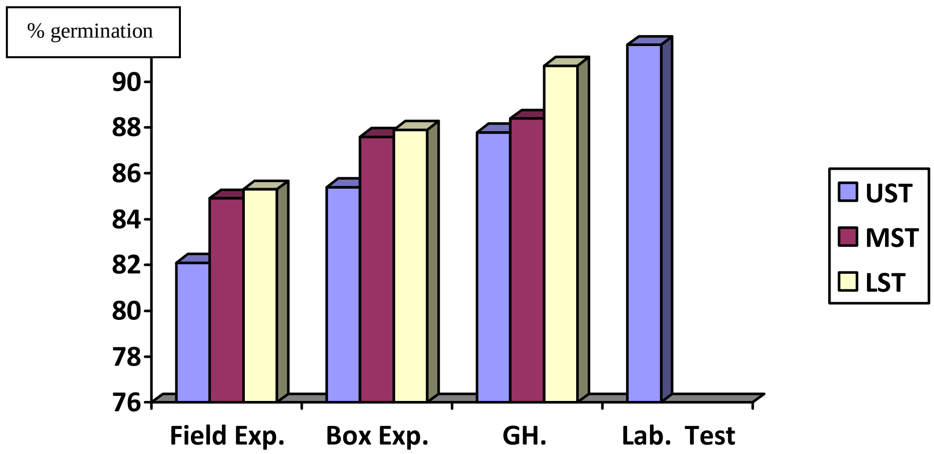



**Fig.15 Comparisons of percent emergence among different slants soil status in various environmental conditions compared to the laboratory test.**

Legend: Lab-Laboratory, Exp.-Experiment, UST-Upper slant terrain, MST-Middle slant terrain, LST – Lower slant terrain

The mean plant height increased with time, showing no significant differences ($P \leq 0.05$) during the growth period (Appendix 9.4). The interaction effect between fertilizer level and sampling interval on the height of the plants is not significant. In the field experiment, the plant height growth rate was not significant ($P \leq 0.05$) between sampling intervals (SI). Between stage 1 and early stage 2 there was no noticeable response to fertilizer when height was generally below 20cm. No significant ($P \leq 0.05$) differences were detected between the growth stages. Height among same growth stages were statistically similar ($P \leq 0.05$) as the ANOVA table appendix 9.4 did not indicate any significant difference. Plants in all the experiments had attained maximum height by 120days after planting indicated by the apical meristem developing into an inflorescent after splitting into two sister branches. Plant height in the field establishment experiment did not attain normal Quartin clover's height (Fig. 16). This could be attributed to soil moisture stress and low fertility status.

**4.7 The pair wise comparison on the effect of Phosphate fertilizer on plant height.**

| | No P(0) | 30kg/ha | 50kg/ha | 60kg/ha |
|---|---|---|---|---|
| 0 kg/ha | 0 | 0.5* | 0.4* | o.4* |
| 30kg/ha | -0.5* | 0 | -0.1 | -0.2 |
| 50kg/ha | -0.4* | 0.1 | 0 | 0.1 |
| 60kg/ha | -0.4* | 0.2 | 0.1 | 0 |

The lower the phosphate level caused less vigor in plants for lateral development therefore, forced plants to grow vertically (Patel *et al*., 1980). Plants in the field Middle slant were apparently more horizontal with comparatively short apical shoot (about 45cm) compared to the average height of 50 –60 cm.

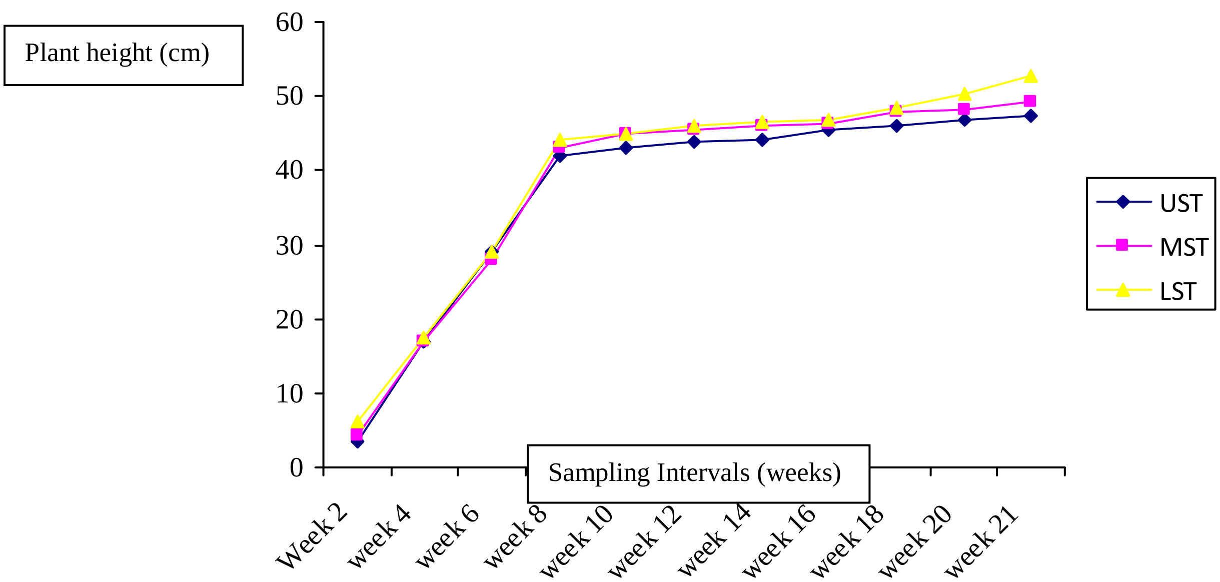



**Fig. 16 Effects of terrain levels on plant height (cm) Quartin clover in the green house experiment**

Legend: UST- Upper slant terrain, MST – Middle slant terrain, LST – Lower slant terrain

On the premise that air temperature is the most important determinant of leaf production in these establishment experiments, the number of leaves per plant increased rapidly initially and then more slowly or decreased. These plants were compact with very short internodes in both vertical and lateral branches. The leaf petioles were also relatively short. Phosphate fertilizer levels had significant effect ($P \leq 0.05$) on leaf number (Appendix 9.8). The results are shown on the comparison table 4.8 shown below:

**4.8 The pair wise comparison on the effect of phosphate on the leaf number.**

| | No P(0kg/Ha) | 30kg/Ha | 50 kg/Ha | 60 kg/Ha |
|---|---|---|---|---|
| No p(0kg/Ha) | 0 | -0.7* | -1.7* | -1.3* |
| 30 kg/Ha | 0.7* | 0 | -0.6* | -1.0* |
| 50 kg/Ha | 1.7* | 0.6* | 0 | -0.4* |
| 60 kg/Ha | 1.3* | 1.0* | 0.4* | 0 |

There is a significant effect of phosphate application on the leaf number, with the 60kg/Ha giving the highest (50 kg/Ha $P_2O_5$ > 60 kg/Ha $P_2O_5$ > 30kg/Ha $P_2O_5$).

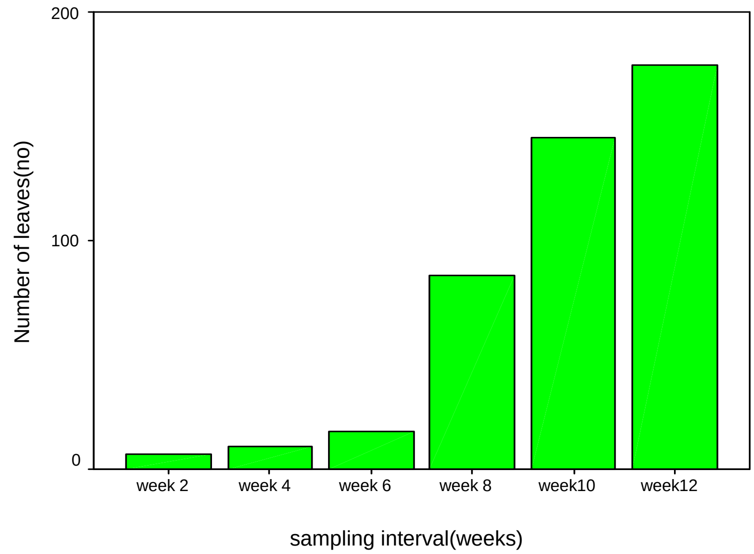



**Fig. 17 Accumulation of leaves in Quartin clover seedlings within 12 weeks after emergence in green house experiment**

The number of main stem nodes and branches per plant were observed and recorded after every 14days. The rate of leaf appearance was determined by the number of nodes and branches, from which the leaves develop. Main stem nodes are the plants basic morphological unit on which branches develop and are supported. Branching occurred after the appearance of the third trifoliate leaf on the main stem node close to the cotyledon leaf and progressed bilaterally. Land slant did not significantly affect the number of main stem branches. Land slant treatment did not have significant ($P \leq 0.05$) effect on number of main stem branches per plant (Appendix 9.5). The reduced number of primary branches in field plots could have been due to soil moisture stress that may have contributed less plant growth vigor.

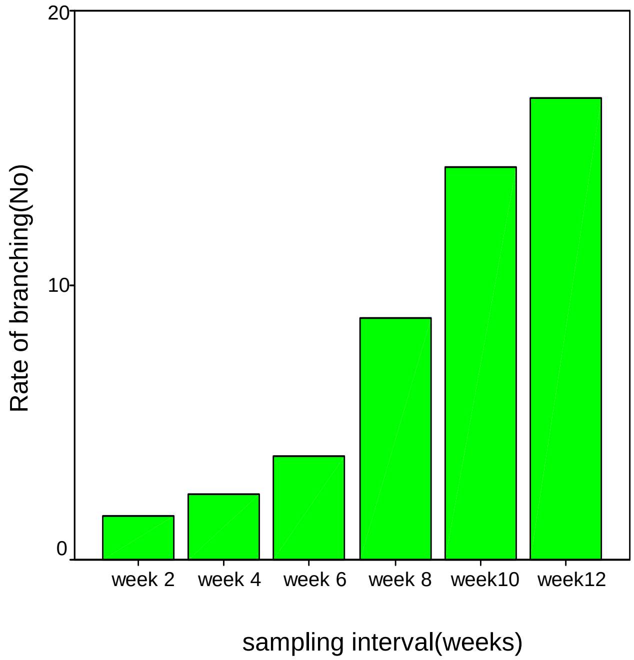



**Fig. 18 The rate of branching in Quartin clover seedlings development**

Assessment of plant cover was based on rating scale of numbers 1 -9 used here only as index Increased plant cover occurred in the early stages of growth (between SI 1 - SI 6) as shown in table 3.1. In the field establishment the normal growth was affected by periods of drought. A plateau occurred in stage 3 and 4 of the plant growth cycle, a period at which plant cover was highest. There after a decline was experienced in the late fourth stage. Lower leaves were shed as the upper leaves gradually dried up and the plants fell to the ground forming a mat. Plant cover during seedling and early active growth stage is scanty and most of the photosynthetic active radiation (PAR) is not intercepted by the canopy hence slow dry matter accumulation. As percent plant cover increases (Fig.19), a lot of incident PAR is intercepted which in turn causes the plant to grow and increase in dry matter yield, especially if moisture in the soil is not limiting.

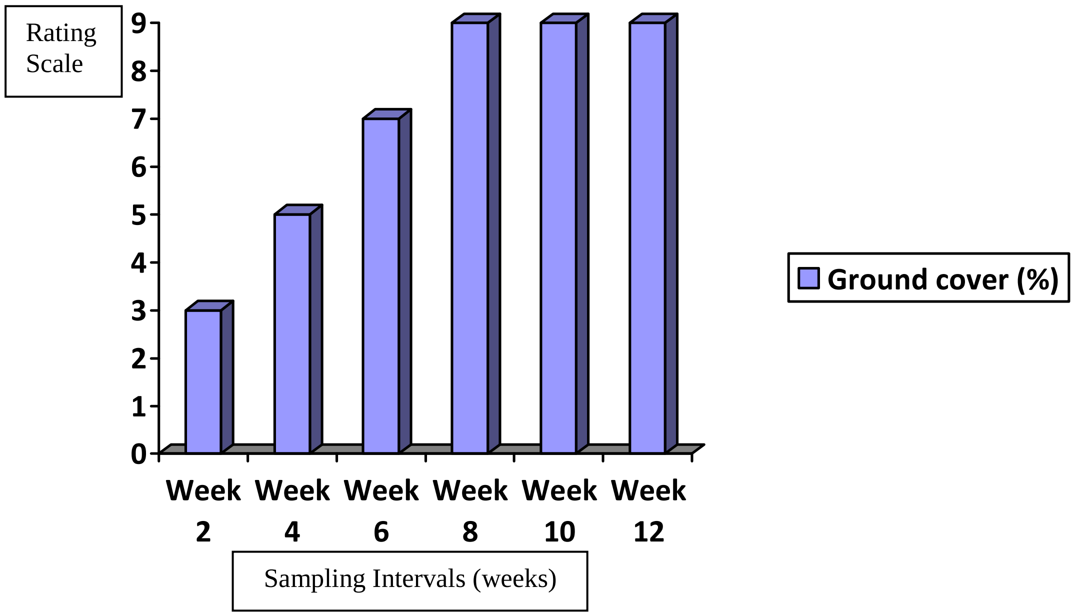



**Fig. 19 Percent ground cover in Quartin clover seedlings as per the rating scale 1-9**

Nodules formation in field establishment

There was no evidence of nodule formation in the first two weeks after emergence of the seedlings. However response of nodules to Phosphate fertilizer application became apparent in the fourth week and increased steadily to eight week. Fertilizer application had highly significant ($P \leq 0.05$) different on nodules formation (Appendix 10)

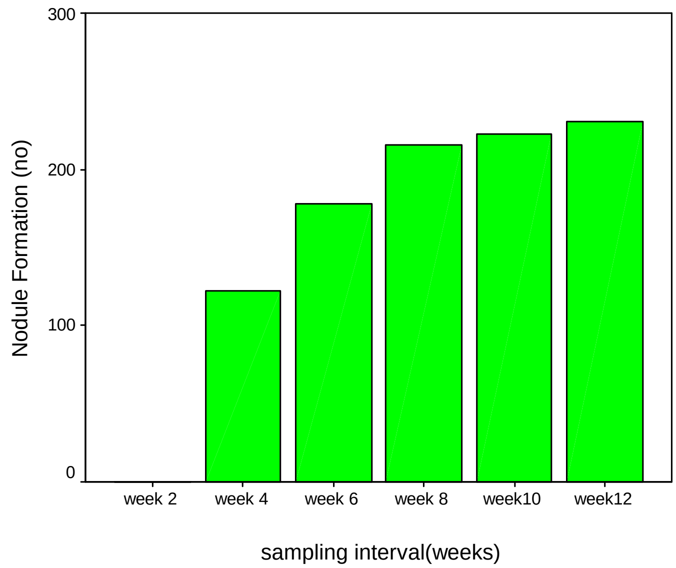



**Fig. 20 Rate of nodule formation in Quartin clover seedlings**

Seed yield

The differences in seed yield (tons per hectare) among the three field treatments may be explained by differences in the number of seeds per plant and seed weight. Larger plants may have produced either more inflorescent plant$^{-1}$ and/or more seeds per inflorescent. High temperature (24.4$^0$C and 27.6$^0$C) in January and February 2007 respectively adversely affected seed filling in the field hence reducing productivity. There was a significant ($P \leq 0.05$) difference between upper slant treatments (Appendix 9.1 a, b and c). The quantity of seeds harvested was 0.5078, 0.4663 and 0.4543 tons ha$^{-1}$ in field establishment, 0.610, 0.572, and 0.546 tons ha$^{-1}$ in box plots and 0.522, 0.434, 0.562 tons ha$^{-1}$ in green house establishment in the lower, middle and upper slant terrain respectively. The seed yield was significantly ($P \leq 0.05$) lower in the upper and the middle slant terrain than in the lower slant terrain in the three establishments. This difference could be attributed to soil moisture content and low fertility levels. Total evaporation was high towards maturation stage adversely affecting the field establishment seed filling as opposed to box plots which were irrigated dairy. Heavy rains during the maturation stage caused the plants to rejuvenate hence extending the growing season. This change of weather caused Quartin clover to behave as a biennial with unsynchronized seed production, which made harvesting a very difficult and expensive task.

Dry matter yield

**Table 4.9 Pair wise comparison on the effect of Phosphate on the dry matter yield of Quartin clover**

| | No P(0kg/Ha) | 30kg/ha | 50 kg/Ha | 60kg/Ha |
|---|---|---|---|---|
| No P (0kg/Ha) | 0 | -0.9* | -1.1* | -1..5* |
| 30kg/Ha | 0.9* | 0 | -0.3 | -0.6* |
| 50kg/Ha | 1.1* | 0.3 | 0 | -0.4 |
| 60kg/Ha | 1.5* | 0.6* | 0.4 | 0 |

The dry matter yields, from the LSD output table above shows that, Phosphate at 50 kg/Ha and 60 kg/Ha have nearly similar yields. The 30 kg/Ha Phosphate level produced less dry matter as compared with the other frequencies. This might be due to the fact that dry matter yield at low fertilizer levels were more effective and hence low dry matter yield

The differences in above ground dry matter are attributed to soil fertility and moisture differences. The dry matter (DM) was significantly ($P \leq 0.05$) in field establishments and box plot establishment. Treatment effect on dry matter were analyzed statistically (ANOVA) see Appendix 9.2 for a typical output. Land gradient showed a significant ($P \leq 0.05$) difference in dry matter yield. The lower slant had significantly higher dry matter yield than the middle and the upper slants. This may be attributed to increased soil moisture and fertility compared to the upper and middle slant. These results indicate that soil moisture content and fertility are the limiting factors to clover growth and development as defined by Akundabweni, (1986). He stated that crop development refers to changes in the organ formation and is manifested as the onset or termination of different phases of a plants life cycle (i. e germination, flowering, seed growth, senescence and maturity). Above ground dry matter (stubble) in those experiments was analyzed at 50% flowering because it is the recommended time for harvesting clover for fodder or hay. Fertilizer treatment in the field establishment and slant treatment in the box establishment showed significant differences ($P \leq 0.05$) in stubble weight(Appendix 9.7 and 9.3 output tables. Dry matter production is proportional to the total amount of radiation (PAR) that is intercepted by the foliage and the efficiency with which it is converted to dry matter by green leaves. The total radiation incident on the canopy varies between locations and seasons and within seasons in a given location.

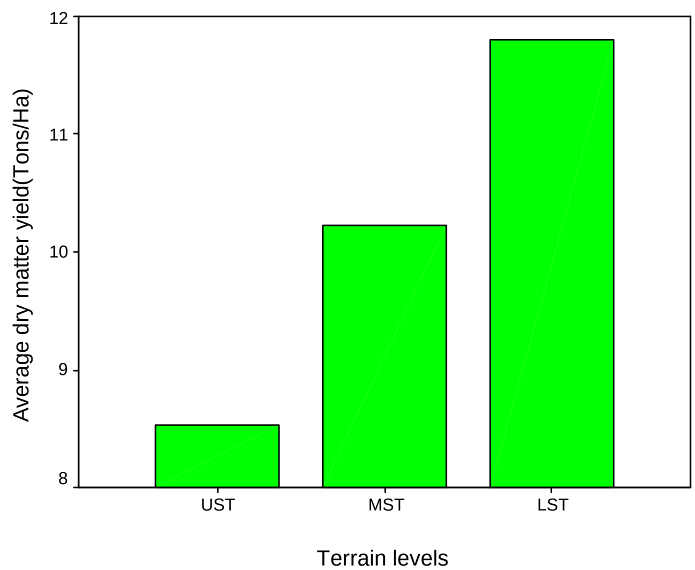



**Figure 21 Effect of terrain level on Accumulation of herbage dry matter in Quartin clover plant**

### 5.5 Conclusions and recommendations

For successful seed germination and crop establishment, the soil must be sufficiently moist. This would ensure adequate opportunity for water uptake by germinating seeds and water loss from the germinating seed should not be excessive.

As percent plant cover increases, more incident PAR is intercepted which in turn causes the plant to grow and increase in dry matter yield, especially if moisture in the soil and soil fertility are not limiting.  Dry matter production is proportional to the total amount of radiation (PAR). The total radiation incident on the canopy varies between locations and seasons and within seasons in a given location, thus proper seed rate should be maintained in order to improve production

High Monthly air temperatures (24.4$^{0}$C and 27.6$^{0}$C) during reproductive phase adversely affected seed filling in the field establishment hence reducing productivity. This study recommends that time of planting  be observed carefully so that the seeding stage corresponds with the wet weather conditions

# CHAPTER SIX

# MINERAL MICRONUTRIENTS DENSITY RESPONSE TO TERRAIN SOIL DIFFERENCES AT KABETE FIELD STATION

## 6.1 Introduction

Mineral micronutrients are necessary elements when included in animal diet. They are needed as trace elements because when they are included in the diet at too high levels may be toxic (Rook and Thomas, 1983). The mineral micronutrients density in Quartin clover increased with increase in time during the early growth stage. The mineral micronutrients that were determined from the soil at the experimental site, the seed clover and the plant tissue include the following; Iodine, Manganese, Iron, Cobalt, Copper, Zinc, Selenium and Molybdenum. The results obtained from XRF spectrometer indicated that there is a relationship between the accumulation of these elements in the plant tissues and their levels in the soil terrain. The annual African clover absorbed this mineral nutrient from the soil and accumulated it in both the herbage and the seed tissues.

## 6.2 Methodology

Mineral micronutrients concentration for Quartin clover analysis undertaken at the Institute of Nuclear Science and Technology of the University of Nairobi which has developed an Energy Dispersive X-Ray Fluorescence(EDXRF) spectrometer based on Cd109 radioisotope source for analysis of trace elements. The plant tissues were compressed using a 7-tons hydraulic hummer in to disc that were subjected to EDXRF spectrometer analysis as illustrated in Fig. 3. Trace elements that were analyzed include selenium, molybdenum, copper, zinc, Manganese and iron. Cobalt and Iodine were also analyzed in the same way.

## 6.3 Results

The soil samples, plant tissues and seed samples were analyzed for mineral micronutrients. Results obtained electronically were represented in Table 5.2 below:

**Table 5.2 Concentration of mineral micronutrients in soil, plant tissues and seed clover in ppm at three different terrain slants levels**

| **Mineral Elements** | **LST** | | | **MST** | | | **UST** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soil | Plant | **Ratio P:S** | Soil | Plant | **Ratio P:S** | Soil | Plant | **Ratio P:S** | seed |
| Iodine (I) | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL |
| Manganese(Mn) | 7170 | 157 | 1:46 | 6910 | 181 | 1:38 | 5800 | 274 | 1:21 | 71.5 |
| Iron (Fe) | 91900 | 543 | 1:169 | 93400 | 324 | 1:288 | 88400 | 642 | 1:137 | 563 |
| Cobalt (Co) | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL |
| Copper (Cu) | 70.80 | 23.2 | 1:3 | 66.30 | 25.7 | 1:3 | 74.80 | 20.4 | 1:4 | 19.5 |
| Zink (Zn) | 289 | 75.9 | 1:4 | 271 | 54.7 | 1:5 | 258 | 93.8 | 1:3 | 102 |
| Selenium (Se) | 0.777 | 3.96 | 1:0.2 | 3.080 | 3.15 | 1:1 | 1.16 | 3.89 | 1:0.3 | 0.855 |
| Molybdenum (Mo) | 6.34 | 1.37 | 1:5 | 7.030 | 0.912 | 1:8 | 4.86 | 0.765 | 1:6 | 11.7 |

Legend: LST= Lower slant terrain, MST= Meddle slant terrain, UST= Upper slant terrain, ppm= parts per million

Ratio P : S = Ratio of plant to soil mineral micronutrients concentration

NB: LDL  The elements concentration has low the detection limit by the metre

### 6.4 Findings

Iron: Iron was the most abundant mineral micronutrients in the three terrain levels compared to all the other elements. The annual African clover absorbed this mineral nutrient from the soil and accumulated it in both the herbage and the seed tissues, which showed to be very rich in iron. Iron compounds are important in nutrition and iron is a requirement in animals and is biologically significant (Cole and Haresigh, 1985). This is because it is an essential component of hemoglobin, a red oxygen-carrying pigment of the red blood cells of vertebrates and muscle pigment myoglobin, Some body enzymes also have a composition, which include iron (Tadesse et al,. 1991). Feeding animals with Quartin clover would improve their health and avoid deficiency of iron which causes anemia.

Manganese: Manganese is the 2$^{nd}$ most abundant mineral micronutrients in Kabete soils. There is a negative correlation between the Manganese concentration in the soil and in plant tissues. The terrain level with the highest concentration of Manganese in the soil has comparatively low concentration in the plant tissue. However the herbage and seed tissues contain considerably high levels of Manganese. This can be used to explain the fact that Manganese has been shown experimentally to be necessary for normal skeletal development in sheep but deficiencies have not been found under grazing conditions (Charles, 1983). As little as 0.5mg/kg of dietary dry matter is sufficient to maintain good growth rate and feed gain ratio in pigs from birth to 90kg live-weight (Fraser and Stamp 1987). Manganese compounds are less toxic than those of other widespread metals such as iron, nickel and copper compounds. However manganese is toxic in excess (Pohanish, 2006) for nearly all organisms living in the presence of oxygen use it to deal with the toxic effects of superoxide, formed from by the 1-electron reduction of dioxygen (Meco et al., 1994).

Iodine: Iodine had a low spectrometer’s detection limit at the experimental site which is also reflected in Quartin clover herbage and seeds. The low level in the soil is reflected in the tissues. Iodine is consumed by animal where between 70 and 80 percent of dietary iodine is absorbed as iodide from the rumen with considerable re-secretion occurring in the abomasums (Miller et al., 1988). Iodide that is secreted into the blood is largely reabsorbed from the small and large intestine hence very small dietary quantities are adequate. Absorbed iodide is largely taken up by the thyroid gland for thyroid hormone synthesis or is excreted in the urine. Iodine is an essential component of the hormone thyroxin. In the thyroid gland it becomes a part of the iodine-containing hormones, which regulate the rate of energy metabolism in the body (Welch et al, 1991, Hetzel, 1986, Hetzel and Marberly, 1986). In lactating cows, approximately 8 percent of dietary iodine is secreted in milk (Miller et al., 1988). Its deficiency leads to an enlargement of the thyroid gland particularly in lambs at birth, referred to as goiter, a swelling of the thyroid, is often a symptom of inadequate iodine in the diet. This is followed by depression of all productive functions and lambs are often stillborn or weakly (Charles, 1983).

Zinc: Zinc concentration in Quartin clover tissues at the three terrain levels was more than 50µ/g which is a clear indication that it is rich in Zinc. Since Zinc is present in all animal tissues and is a component of a number of enzymes, it is required for normal growth and appetite and the functioning of the testes is even more sensitive to deficiencies (Rook &Thomas1983). Zinc deficiency is characterized by growth retardation, loss of appetite, and impaired immune function. In more severe cases, zinc deficiency causes hair loss, diarrhea, delayed sexual maturation, impotence, hypogonadism in males, and eye and skin lesions (Maret Sandstead, 2006, Prasad, 2004). Weight loss, delayed healing of wounds, taste abnormalities, and mental lethargy can also occur but these are unlikely in grazing animals (Rook &Thomas1983) where grazing land has both grasses and forage legumes growing together. Zero grazing animals which in most cases are fed with Napier grass alone are at a risk of Zinc deficiencies. This problem can be alleviated by introducing high quality forage legumes such as Quartin clover into small holder farming systems.

Copper: The concentration of Copper in Quartin clover is approximately 25 µ/g which is half that of Zinc but far much more than that of, Selenium and Molybdenum. Cobalt was at low detection limit. Copper is an essential trace element in plants and animals, but not some microorganisms (Bonham, et al., 2002). It is needed for quite a wide variety of body functions where its deficiency is particularly indicated by in-coordination in newborns lambs and by anemia (Charles, 1983; Fraser and Stamp 1987) and poor growth in adults. A minimum dietary value for healthy growth in rabbits has been reported to be at least 3 ppm in the diet. However, higher concentrations of copper (100 ppm, 200 ppm, or 500 ppm) in the diet of rabbits may favorably influence feed conversion efficiency, growth rates, and carcass dressing percentages (Ayyat, et al., 1995). Feeding animals with Quartin clover which is rich in Copper can be can satisfy hidden hunger since Copper is essential in enzymes required for heart function, bone formation, energy metabolism, elastin synthesis, normal hair growth and red blood cell formation. (Encyclopaedia of Food Science and Food Tech., 1993).

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Although soils at Kabete field station has considerable amount of Cobalt, very small amounts were absorbed and retained by the plant. The results show that the highest concentration of 5.83µ/g was recorded in plant at the middle slant terrain which had the highest concentration in the soil. Research has shown that luminal flora does not have any store of cobalt available and so daily intake is necessary (Charles, 1983; Nickerson, 1978). Cobalt is an essential component of Vitamin $B_{12}$ which is manufactured by rumen micro flora. A deficiency leads to depression of all productive functions; perhaps most notably stunt growth, anemia and stillborn lambs. This is why this research work recommends that farmer integrate Quartin clover in their mixed farming systems to alleviate such deficiency symptoms.

Molybdenum: There was very low concentration of Selenium and Molybdenum in both the soil and the in the plant tissues and could hardly be detected in some samples. Selenium is one of the elements needed in trace amounts in the animal and human diet. Selenium is important for animal muscular development and when deficient leads to degeneration of muscles, particularly of the hindquarters and arthritis (Stone *et, al.*, 1997). It is in suckling lambs (when muscle development is at the peak) that is the most susceptible to this condition. Selenium is a requirement for cattle while the nutritional value of all plant food depends on the soil in which it was grown, the selenium content of plants seems particularly sensitive to soil concentrations (Charles,1983). For this reason, most of the early research on selenium focused on diseases in sheep, cattle, turkeys, and pigs which involved low soil concentrations of selenium and insufficient amounts of selenium in the forage plants eaten by these animals. It is important to remember that the selenium content of food is highly variable because it depends so heavily on soil conditions. While soil conditions affect plant foods most directly, they also affect animal foods, since most animals depend upon plants for their diet.

Molybdenum is an essential trace element for virtually all life forms as it plays a complex role in animal growth and development. It functions as a cofactor for a number of enzymes that catalyze important chemical transformations in the global carbon, nitrogen, and sulfur cycles. Thus, molybdenum-dependent enzymes are not only required for human health, but also for the health of our ecosystem (Lide, ed. (2005). It is good to feed animals with feeds that contain small quantities of Molybdenum because Excess dietary molybdenum has been found to result in copper deficiency in grazing animals (ruminants). In ruminants, the formation of compounds containing sulfur and molybdenum, known as thiomolybdates, appears to prevent the absorption of copper (Jane Higdon, 2001). Small quantities are beneficial. Deficient diet encourages excessive copper storage with the associated risks mentioned above. High levels of molybdenum cause scouring and induce copper deficiency. The balance between molybdenum and copper is also affected by intake of sulfate with high levels increasing the danger of molybdenum toxicity (Nickerson, 1976).

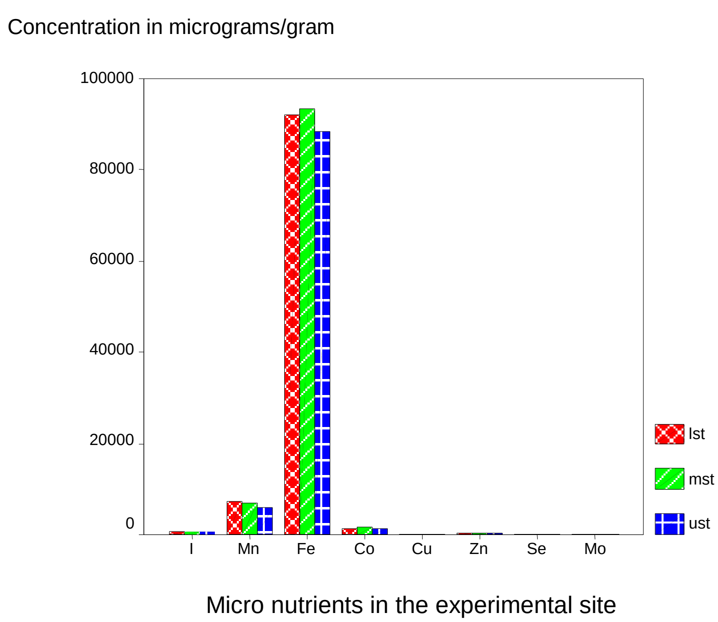



**Fig.22. Concentration (μ/g) of mineral microelements at the experiment site**

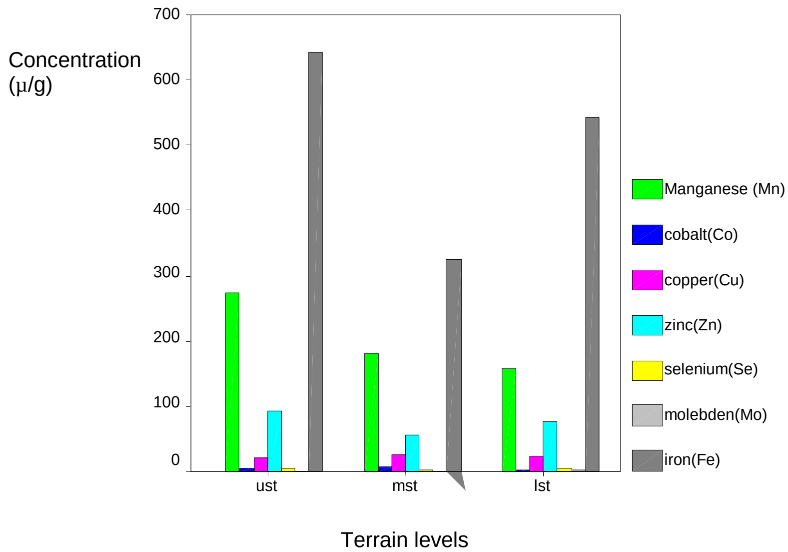



**Fig. 23 The effect of terrain level on mineral micronutrients (µ/g) accumulation of in Quartin clover herbage**

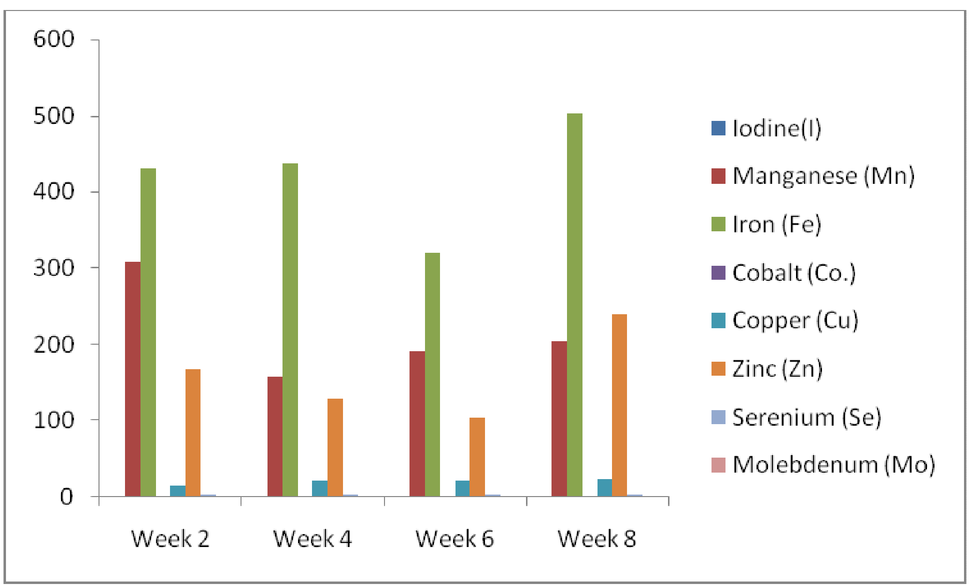



**Fig. 24 Concentration of mineral micronutrients (µ/g) in Quartin clover herbage**

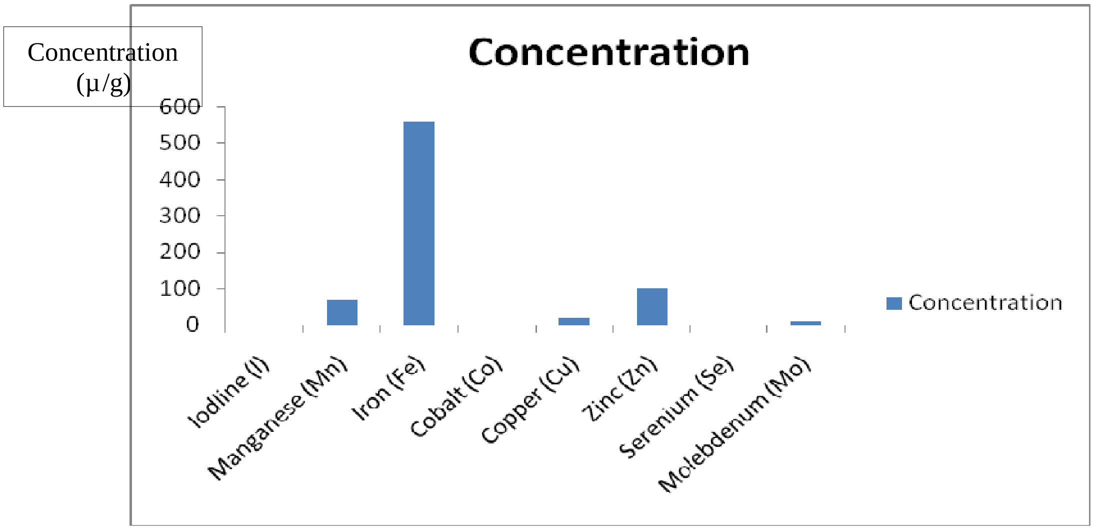



**Fig. 25 Concentration of mineral micronutrients (μ/g) in Quartin clover seeds**

### 6.5 Conclusions

1. Both plant tissues and seeds have high levels of mineral micronutrients which if feed to animals can contribute greatly to satisfying hidden hunger. The high level of iron in the plant tissues is important in incalf, lactating animals and the young ones due to their high demand for iron to aid milk production, rapid growth and development together with other health issues.
2. Weight loss, delayed healing of wounds, taste abnormalities, and mental lethargy can also occur but these are unlikely in grazing animals (Rook &Thomas1983) where grazing land has both grasses and forage legumes growing together. Zero grazing animals which in most cases are fed with Napier grass alone are at a risk of Zinc deficiencies. This problem can be alleviated by introducing high quality forage legumes such as Quartin clover into small holder farming systems.
3. Quartin clover absorbed Zinc from the soil and had impressive levels of Zinc in both the seed and the herbage. It is an essential component of the normal body functions in both man and animals.

# CHAPTER SEVEN

# EFFECT OF PHOSPHATE ON ACCUMULATION OF MINERAL MICRONUTRIENTS IN QUARTIN CLOVER HERBAGE

## 7.1 Introduction

The tissue elemental concentration variation in plants is based on genetic differences among species and the species extent of uptake of mineral nutrients from the soil (Shacklette, 1980). Soil condition and climate are factors that influence not only growth but also subsequent dry matter yield accumulation and nutritive quality of clover (Kahurananga *et al*., 1984). Application of phosphorous has been shown to increase dry matter yield, percent phosphorus of pasture legumes and nitrogen in pasture legumes (Muthoni, 2000). Phosphorus has been shown to increase dry matter yield of annual clover (Haque and Lupwayi, 1998, 1999; Mugwira *et al*., 1997. This experiment was carried out to determine the effect of phosphate on accumulation of micro nutrients in Quartin clover using the methodology outlined in chapter 4. It was found that application of phosphorous affected uptake and accumulation mineral micronutrients as presented in the following results.

## 7.2 Methodology

The field was disk ploughed and harrowed three weeks before planting. Plots of dimensions 3m x 3m with a 1m path all around the plots were demarcated using a meter ruler and sticks. Three guard rows of the annual African clover were planted along the edges of the experimental site. The experiment was arranged in Randomized Complete Block Design (CRBD). The experiment site was in un- even gradient, therefore it was divided into 3 slants namely: Upper, Middle, and lower slant terrain which were considered as a natural treatment. Four phosphate fertilizer levels were applied as treatments and replicated four times. The treatments were: O $kgP_20_5$/Ha, $30kgP_20_5$/Ha, $50kgP_20_5$/Ha and $60kgP_20_5$/Ha. The design was chosen to test the effect of three land slant level locations and four fertilizer levels on herbage growth and the accumulation of mineral micronutrients in Quartin clover. Data was collected, recorded and analyzed using EDXRF Spectrometer.

### 7.3 Results

The results obtained from XRF-Spectrometer and Multichannel analyzer were recorded in the Table 5.3 below:

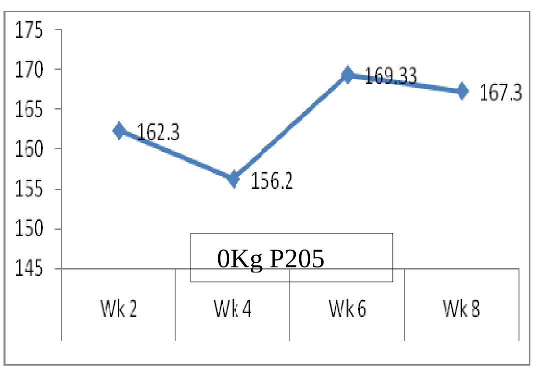
**Table 5.3 Accumulation of mineral micronutrients (ppm) in Quartin clover seedlings up to 8 weeks of growth**

| | 0 Kg $P_20_5$ | | | | 30 Kg $P_20_5$ | | | | 50Kg $P_20_5$ | | | | 60kg $P_20_5$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minerals | Wk 2 | Wk 4 | Wk 6 | Wk 8 | Wk 2 | Wk 4 | Wk 6 | Wk 8 | Wk 2 | Wk 4 | Wk 6 | Wk 8 | Wk 2 | Wk 4 | Wk 6 | Wk 8 |
| Mn | 162.3 | 176.3 | 169.33 | 167.3 | 179.3 | 139.3 | 174.7 | 202.3 | 208.33 | 158 | 190.7 | 152.3 | 160 | 114 | 149 | 154 |
| Fe | 313 | 372.3 | 412 | 307.7 | 356 | 321 | 291 | 367 | 431 | 338 | 320.3 | 449.7 | 259 | 278.7 | 285 | 486 |
| I | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL |
| Co | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL | LDL |
| Cu | 12.37 | 17.7 | 20.67 | 21.83 | 13.7 | 17.9 | 21.63 | 19.8 | 15.73 | 21.77 | 21.8 | 26.37 | 11.7 | 15.1 | 18.4 | 21.33 |
| Zn | 134 | 139.7 | 113 | 90.63 | 147.7 | 109.3 | 96.3 | 85.57 | 168 | 129.2 | 104 | 94.77 | 111 | 129.3 | 101 | 69.03 |
| Se | 2.46 | 2.71 | 1.72 | 1.38 | 2.76 | 1.08 | 3.38 | 3.33 | 2.67 | 3.2 | 2.75 | 4.51 | 3.79 | 2.76 | 2.24 | 2.56 |
| Mo | 1.99 | 2 | 1.5 | 1.2 | 2.32 | 1.41 | 1.12 | 1.53 | 2.42 | 1.34 | 1.06 | 1.99 | 1.92 | 1.15 | 1.24 | 1.34 |

LDL(Low detectionLimit)

### 7.4 Findings

Rate of phosphate applied at planting time leads to development of the herbage, which provides necessary photo-assimilates thus enhancing nodulation and BNF (Jutzi and Haque,1984). Legumes use available soil nitrogen before nodulation and fixing nitrogen symbiotically ( Heichel *et al*.,1984a). Fertilizer application increased dry matter yield, leaf nitrogen and phosphorous level of runner bean (Kahuro, 1990). Reneau *et al*., (1983) working on sorghum reported that phosphorus fertilizer increased nitrogen concentration sorghum. Application of phosphorous has been shown to increase dry matter yield, percent phosphorus of pasture legumes and nitrogen in pasture legumes (Muthoni, 2001). Phosphorus has been shown to increase dry matter yield of annual clover (Haque and Lupwayi, 1998, 1999; Mugwira *et al.,* 1997; Haque and Mugwira , 1991; Kahurananga,1991; Kong *et al*., 1993; Akundabweni, 1984a, 1984b) in the current study, it was found that application of phosphorous affected uptake and accumulation mineral micronutrients in annual African clover differently as shown in the figures below



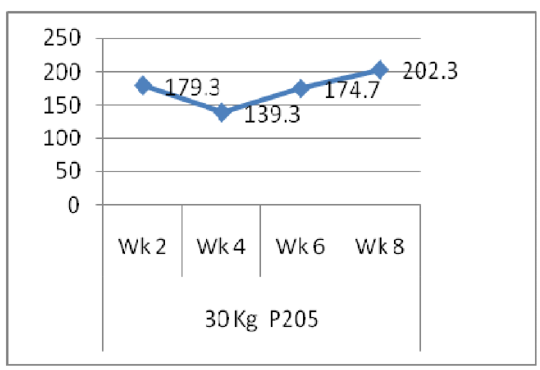
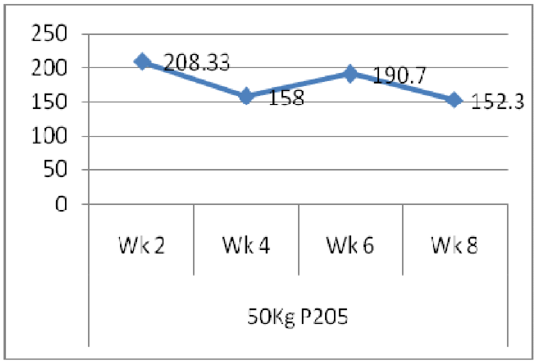




**Fig. 26a Accumulation of Manganese in Manganese in Quartin clover seedlings**

**Fig. 26b Accumulation of in Quartin clover seedlings**



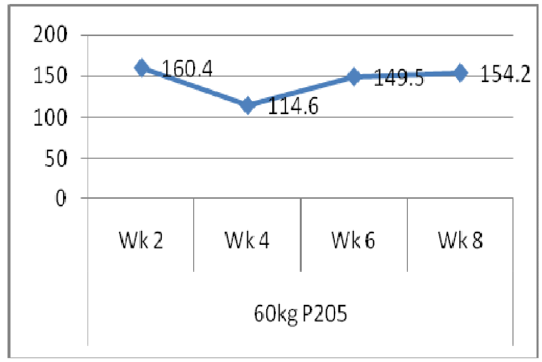
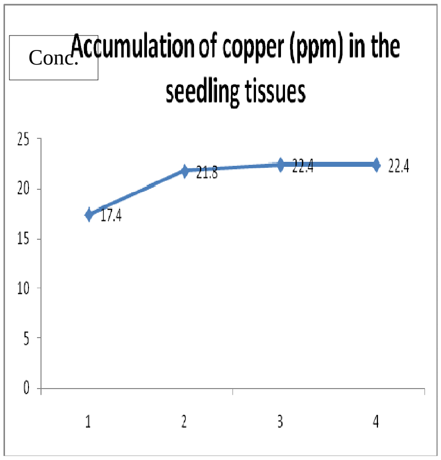



**Fig. 26c. Accumulation of Manganese in in Quaritn clover seedlings**

**Fig. 26d Accumulation of Manganese Quartin clover seedlings**

Manganese concentration in Quartin clover seedlings (Fig 26a,b,c and d) was influenced by the level of throughout the growth period regardless of the level of phosphate. The herbage and seed tissues contain considerably high levels of Manganese. There was a general trend of decline in levels of tissues manganese concentration from week 2 to week 4 followed by a steady rise in week 6 when roots had fully developed to aid absoption

Annual African clover accumulated high concentration of iron in its tissues. The highest concentration at week 8 of growth at both 50 and 60kgha$^{-1}$ Application of phosphorous has been shown to increase Iron concentration in the tissues through enhanced root and herbage tissues development dry matter (Haque and Lapwayi, 1998; Kong et al., 1993). Ion of phosphorus at 60kgha$^{-1}$ negatively affected the accumulation of Fe in this clover since it affected the minerals availability to plants.



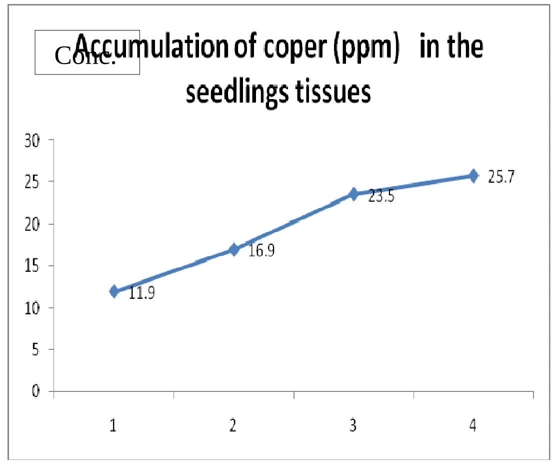




Fig. 27a Effects of Phosphate on acc copper in the seedling tissues at UST

Fig. 27b Effects of Phosphate on acc. of of copper in the seedling tissues at MST

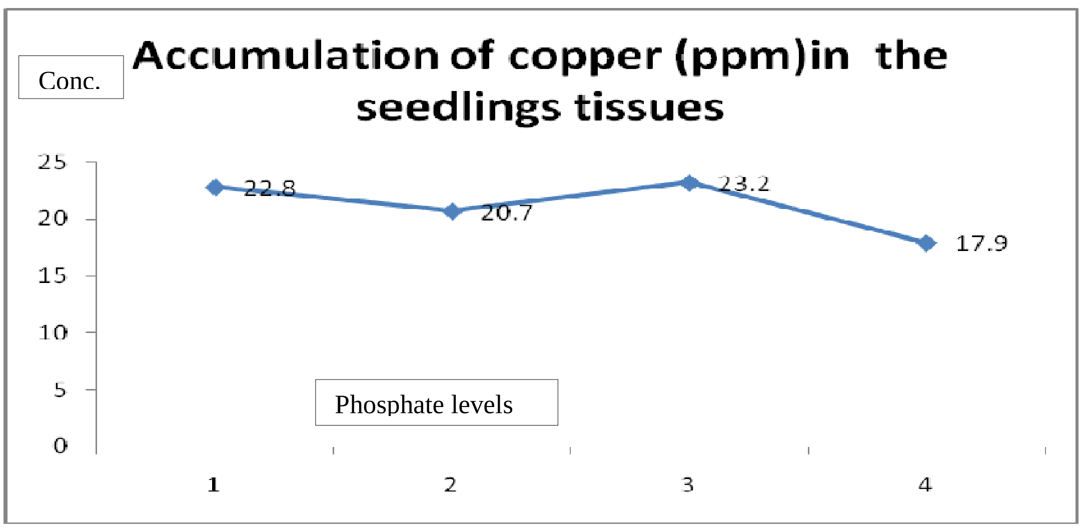
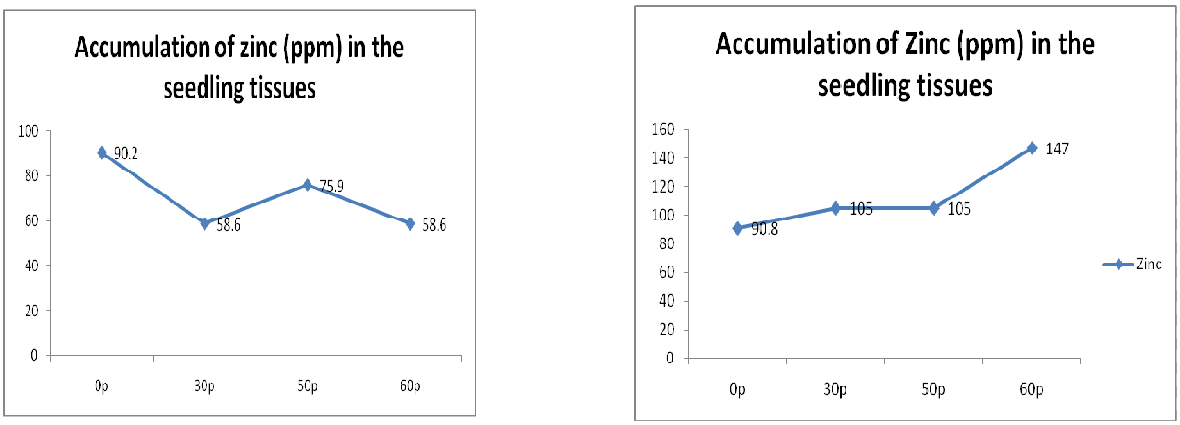



**Fig. 27c Effects of Phosphate on Accumulation of copper in the seedling tissues at LST**

Legend: 1 = O kg/Ha, $P_20_5$2 = 30 kg/Ha $P_20_5$, 3 = 50 kg/Ha $P_20_5$ and 4 = 60 kg/Ha.$P_20_5$

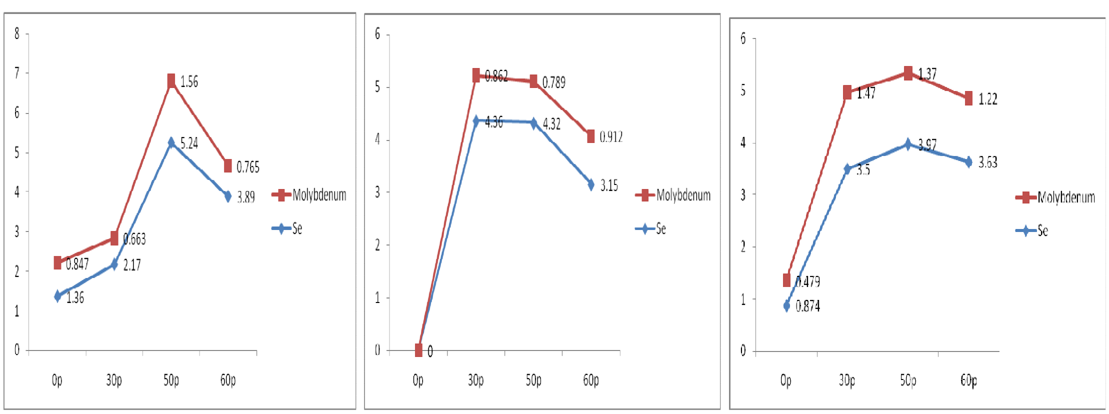
The concentration of Copper in Quartin clover was between 15ppm and 25ppm .It increased gradually with increased in time and phosphate levels. The concentration of Iodine followed the Chronological trend in all the four levels of phosphate fertilizer showing a steady gradual increase in concentration with time.

Concentration of Iodine could not be detected by EDXRF system . This is because Quartin clover experience rapid growth with elongation of internodes and cellulose hardening in the stem and the internodes hence reduction of concentration of micro-elements in weight per weight .




a) LST b) MST

**Fig.28, b. Effects of phosphate on accumulation of Zinc, in Quartin clover within 8 week.**




a) UST b) MST c) LST

**Fig. 29a, b, c Effect of Phosphate on accumulation of selenium and Molybdenum in Quartin clover seedling within 8 weeks of growth.**

Selenium and Molybdenum concentration was the lowest in Quartin clover herbage. But since they are required by animals in very small quantities, feeding Quartin clover to livestock will survise. Cobalt steadily increased from the lowest concentration of 1.11µ/g to 5.25 µ/g in week 4 and week 8 respectively at with very little variations among other fertilizer levels. There was limited absorption of selenium from the soil at low and high levels of phosphorous in the soil. Highest absorption and storage of the element was at 50kg $P_20_5$. Molybdenum concentration was shown to decrease with time during clovers seedling stage. Annual African clover did not respond to phosphorous as far as molybdenum accumulation in plant tissues is concerned.

**7.5 Conclusion and recommendations**

Application of phosphorous affected uptake and accumulation of some mineral micronutrients in annual African clover differently or indirectly through chemical interactions in the soil. The highest concentration of Iron was at week 8 of growth at both 50kgha$^{-1}$ $P_2O_5$. Application of phosphorous has been shown to increase Iron concentration in the tissues through enhanced root and herbage tissues development. There was interaction between level of phosphate fertilizer, accumulation of different mineral micronutrients and the growth stages

# CHAPTER EIGHT

# GENERAL DISCUSSION

## 8.1 General information

### 8.1.1 Growth and development

Quartin clover Germplasm was selected from the Ethiopian highlands by professor Akundabweni through intensive studies on agronomic adaptability and performance. Its phonological stages were divided into four growth stages (Muthoni, 2000) which were confirmed in Quartin clover growth assessment. They are seedling stage, $2^{nd}$ growth stages or rapid vegetative growth stage, $3^{rd}$ growth stage or maturation stage, and $4^{th}$ growth stage or senescent stage and death. During seedling stage, there was slow growth. This slow growth could be due to few and small leaves causing photosynthesis to be slow. The roots at this stage were not well established hence limiting the uptake of water and mineral nutrients. Plants in the field experiment were prone to wilting due to moisture stress during days of no rainfall. The plant absorbed mineral micronutrients from the soil showing interaction between the terrain level and the plant. The early maturation stage was characterized by flowering and seed formation (seed set) and accumulation of mineral micronutrients translocation from other plant tissues to the seed for storage. Weather conditions especially soil moisture stress has adverse effect on the plants growing in the open field. Fourth stage or simply post flowering stage (120 days and above) represented as Sampling Interval 9 – Sampling Interval 12) was a slow development phase, seeds were formed, inflorescent dried, cover and leave number declined while the plants fell over to form a mate. These growth stage of Quartin clover conformed to the growth cycle of annual crops (Herridge and Pate, 1977). Climatic factors affects forage quality by determining the duration of plant growth stages. This is especially important for the immature or juvenile stage, when leaves predominate. Plant age is an important factor as far as forage quality is concerned. It is the plants' age which determines quality.

Terrain environment as affected by environmental conditions such as rainfall, relative humidity, temperature, and a factor on the physio-chemical characteristics (terrain factors) such as mineral micronutrients contents, soil moisture content, erosion and leaching of minerals which in turn affects minerals mineral micronutrients flow between the soil and the plant.

Vegetative mineral micronutrients uptake from the soil during growing season was demonstrated by accumulation of the mineral micronutrients it the plant tissues

The experimental site specific seasonal effect on seed mineral micronutrients density in event showed that the genotype environment effects were strong. At 50% flowering, the plant had accumulated considerable amount of mineral micro nutrients as shown in the results.

### 8.1.2 Weather conditions at the experimental site.

Climate data was collected in order to access the difference between the growing seasons and meteorological variables likely to influence growth of Quartin clover. The variables investigated include:

i. Temperature minimum and maximum temperature,
ii. Atmospheric humidity: mean monthly daytime relative humidity (0900 and 1500hours East Africa Standard time) and
iii. Rainfall: Total and mean daily and monthly rainfall, number of rainy days and total evaporation.

The total rainfall during the study year was 922.34mm for season 1 and 489.01 for season 2. In season 1 there were 12days with rainfall greater than 25mm and a total of 25 days when rainfall was higher than 10mm (Fig 1a). The highest amount received on any one day was 129mm in January 2006. Five months namely February, March, June, July and August received less than 5mm of rainfall per day on average basis while only April had an average more than 10mm per day. The highest total rainfall in season 2 was 118.3mm in November received in 20days. However the average daily rainfall was less than 3mm through out the season.

Total evaporation in season 1 was 101.2mm in July 2006. Total evaporation was very high ranging from 113.4 - 174mm in season 2. Season 2 had a short dry spell in September and a prolonged dry spell from December to March with only 2 days in

January and 1 in February with total rainfall more than 10mm, long rains were well distributed through out the season. Too vigorous growth of the vegetative part could jeopardize seed production hence low seeds production. Long rainfall duration can enhanced establishment, growth and maturity of the clover.

There were two drought periods during the study period(Fig 9a). This weather condition affected the growth of the clover as indicated by the results of dry matter yield and seed production in the field establishment. This could mean that natural conditions as pertains to season of planting, rainfall sufficiency and duration under rain fed conditions might need to be critically evaluated in relation to irrigation intervention. Due to changing climate conditions, September/October as a calendar time appears to be irrelevant in timing of planting. Poor timing can lead to total crop-seed failure; such a tragedy was experienced in trial establishment of Quartin clover planted in November, 1998 followed by heavy March rains in the following year at flowering. Inflorescences were destroyed and no seed was harvested (Akundabweni personal communication).

Average air temperature during the study period was higher than 10year mean for all the months except April and September. Generally temperatures are lower in May, August period compared to the other periods of the year at Kabete. There seems to be a rainfall temperature interaction in the growth of Quartin clover since the crop planted in September and supplied with optimum soil moisture (unpublished data) yielded higher than the one planted in February where the mean monthly temperature at maturation stage was between 18.3 $^{0}$C to 25.2 $^{0}$C and 20.6 $^{0}$C to 27.6 $^{0}$C respectively. This could have agronomic implications with respect to time of planting. This could be evaluated further as several scenarios pointed above indicated that the best time of planting of Quartin clover is yet to be established. Kayinde, (2000) had suggested that the early year planting of Quartin clover in the warmer Jan-June favored a high seed production than the cooler mid-year July -December planting. The months of April, October and November 2007 had considerably more number of rainy day during the study period than 10year mean. During the rest of the period the number of rainy days were either equal slightly more or slightly less than 10year mean.

### 8.1.3 Rainfall

Total rainfall and its seasonal distribution at Kabete varied considerably between the cropping seasons. Drought condition prevailed through February and May 2006, June to October 2006 and December 2006 to February 2007. Some plant died in October 2006 (seedling stage) and February 2007 (flowering stage) because of moisture stress. Terrain slant which has a bearing in moisture retention had significant ($P \leq 0.05$) effect on seed and dry matter yields (See Appendix 9.1 and 9.2). As expected, more seeds were harvested in the lower slant terrain which had higher soil moisture during the growing season.

These qualitative observations are supported by quantitative measurements of soil moisture content made throughout the growing season (Table 4.5). It shows that the in-situ variation in average soil water content at a depth of 30cm (Figure 12). These results show that soil water regimes and crop yields are strongly influenced by rainfall amount and distribution and average air temperature. As expected, the driest profile and lowest yield were observed in the upper slant terrain. Though water supply was the same, there are differences among the slants in climatic water availability; soil water storage and water use.

As shown earlier, seasonal distribution of rainfall is of major importance particularly for the growing of annual clover (Akundabweni 1984). If great proportions of the rainfall showers are light, they add little to the ground water storage and are soon lost by surface evaporation. Often the bulk of rainfall arrives in a few heavy showers Fig.9a illustrates this point. Most unprotected soil surfaces are unable to absorb very high intensity showers (Akundabweni and Njuguna, 1996) and much of this water may be lost through surface runoff. With very heavy showers, surface run off may be over 60 to 70% of the rainfall received (Gibbon and Addam 1965).

### 8.1.4 Air temperature

The average air temperature at Kabete during the growing seasons was presented as (Fig.11). The highest monthly maximum temperature was 27.60C in the month of

February 2007. It was much higher than 10 year mean to an extent that it triggered a public outcry that such high temperatures have not been recorded in Nairobi and its environs for the last 20 years (Fig 9b). June was the coolest month unlike other years when July, August and October are usually the coolest. The air temperature was generally higher than the decade mean throughout the growing seasons except in April and September 2006 (Fig 9b). The high temperatures in the short rains growing season did not favor the crop because of inadequate soil moisture and very high total evaporation.

### 8.1.5 Atmospheric humidity regime.

The relative humidity during the entire study time indicates that there were generally more sunshine hours in the short rain season than in the long rain season. * Indicates where data is missing. The month of January and February 2007 had the highest average number of sunshine hours and the lowest percent relative humidity both at 0060h and 0012h. At the same time there was very high air temperature (Fig.11) and total evaporation and very few rainy days. Relative humidity was generally low during the night and in the morning and remained between 60 to 80% till morning. The highest daytime RH recorded was 64%. In April 2006 while the lowest RH recorded was 38% in February 2007. Low daytime %RH coupled with high temperatures caused moisture stress to the growing crop reducing growth rate. This weather condition corresponds with the seed filling and the maturation stage of Quartin clover adversely affecting seed production.

### 8.1.6 Percentage soil water content

Soil water content was measured gravimetrically from 0 to 30cm depth in the field experiment (Figure 12) throughout the growing season. Any changes in percentage water content during the rain free periods were assumed to be due to evapo-transpiration, i.e. evaporation from the soil surface and water uptake by roots and subsequent loss from the leaves. The longest dry periods were September, December and February example of water depletion patterns are shown in figure 5a. October 2006 and January 2007 had the lowest percent soil water content of about 15% both in upper and middle slant terrain. That of the lower slant terrain did not fall below 20%. The month of November 2006 and

April 2007 had the highest percent soil water content for all the three land partitions. However the lower slant terrain had the highest moisture content in those two months (33.58%). The highest range in percent soil water content throughout the growing season was 18.61 in the upper slant terrain (Figure 12). This fluctuation in soil moisture content adversely affected plants in the upper and middle slant terrain causing some of them to wilt or die. This is because water is a major constituent of plant tissue, a solvent in which solutes including mineral nutrients are transported. It is a reactant in processes like photosynthesis and hydrolysis, is important in maintenance of turgidity and regulation of leaf temperature (Kiomer, 1983). On a worldwide scale water is the most important factor-limiting crop yield (Wondafrash, 1999; Akundabweni et al,. 1991). Crop productivity has been expressed on the basis of dry matter produced per unit water evaporated from a unit of land area. Therefore the productivity depends on the partitioning of water inputs between unproductive losses of water (i.e. through direct evaporation, surface run off, drainage and uptake by weeds) and water used for dry matter production i.e. transpiration) in a cropping system when supplies are adequate, nutrition is commonly the most limiting.

The differences in the dry matter production are attributed to soil fertility and water availability among the land partitions. The results suggest a water*fertility interaction in the growth and development of Quartin clover. The crop in the upper slant terrain experienced severe water deficits in the dry periods. Some sections of the middle slant terrain also experienced the drought but those in the lower slant did not experience such water deficits in the upper and middle slant terrain especially in the wet periods. Surplus water drained as surface runoff carrying fertile soil to the lower parts in the lower part of the farm where water drained into deep percolation and/or surface runoff. For other systems excess water will go into deep percolation (Kironchi, 1992) and thus feed river and ground water.

When the amount of precipitation in a locality is insufficient, crop growth is reduced since soil may not respond to fertilizer addition if native fertility is adequate to produce the crop yield permitted by the moisture regime (John Ryan and Abdullar 1998). The highest moisture content in the soil was attained in the month of November i.e. 33.58%, 31.03% and 30.78% for the lower, middle and upper slant terrain respectively. These regimes corresponded with the late seedling stage (stage I) and early active vegetative growth stage (stage 2). However the moisture content dropped drastically between the month of November and January adversely affecting the growth and development of clover. Plant height was grossly affected in the field and was only a third of the average height of clover plant.

Many plants in the upper and middle slant terrain were wilting during daytime and regained their turgidity at night. A number of them wilted permanently and died during the drought periods. Differences in soil water content among the land partitions were more pronounced soon after rainfall with the upper slant having the highest level between December and January 2006. During this period, there were two lowest peaks of percent water contents; one in January (15.02%) and February (17.6%) both in the upper slant terrain.

The seasonal pattern of moisture availability in the soil for plant transpiration and evaporation is also important particularly where rain fall over a very limited period in the year. The pattern of moisture availability has great significance because it determines the severity of the principle constraint on agriculture. Mean rainfall may be a poor guide to reliability of moisture availability as many areas experience more years with annual rainfall less than the long term mean than with rainfall above it (Gibbon and Addam 1965)

When dry soil is wetted by rainfall or irrigation, redistribution of water in the soil during and after watering occur along energy gradient. Initially the gradient of matrix and gravitational potential cause in well drained soils, rapid downward movement of water into the dry soil, with emptying of large pores over 24 - 48 hours, the hydraulic conductivity is markedly reduced as is the rate of drainage probably by a factor of 100. The water remaining in the small pores is retained by capillarity and surface forces and drain (drain slowly) under gravity in fine textured soils, large pores and few, downward drainage rate is slow right from the beginning and remain for some days. Wilting of plants under field condition did not depend only on soil moisture suction but also on the potential evapo-transpiration, the ability of the plants root to ramify into the soil (depending on growth stages) because wilting was observed during seedling stage and maturation stage. However, wilting does not occur at a fixed soil moisture sanction for different growth stages and for different plant types but over a range of percent moisture content.

All crops require a favorable root environment and favorable water supply for good production. Clover in particular, more than many crops is sensitive to water deficit (Akundabweni et al., 1991). The main objective of irrigation is to prevent lack of moisture from becoming the factor limiting to plant growth (wondafrash, 1999; Kahurananga and Tseley, 1984). Timely irrigation is essential if a clover farmer is to obtain maximum benefits for other cultural practices. Clover yield will be adversely affected if water is scarce in the field (Akundabweni et al., 1991). It is important to irrigate the crop during seedling stage since the roots are not well established and during flowering and seed filling particularly when the land slant is not uniform (Bogdan, 1968**)**. Good drainage encourages deeper and more extensive root system and the crop can draw upon a target reservoir of soil moisture to carry it over periods of inadequate rainfall during the growing season (McWilliam, 1978). The deep roots are also useful in supplying water to the crop during the maturation period after the rains cease.

Irrigation water must be supplied as often as required to prevent undesired water deficit from developing within the plants (Akundabweni *et al*,. 1993). The aim is to keep roots in contact with available soil moisture. Young clovers have a very sparse root system, thus it is quite possible for such plants to suffer a water deficit sufficient to retard growth even though the soil appears to be quite moist. Annual African clover is particularly sensitive to moisture deficit at the flowering stage (Bogdan, 1968**)**. Therefore if rains are inadequate, irrigation should be applied. Just enough water should be given to replace that which has been lost through evaporation from the soil profile and through transpiration from plant leaves. Excessive loss of water by deep percolation below the root zone should be avoided as it contributes substantially to water logging of soils and carry plant nutrients below the root zone (McWilliam, 1978).

### 8.2 Herbage growth of Quartin clover along three terrain gradients

#### 8.2.1 Seed germination and establishment

Soil must be sufficiently moist for successful seed germination and plant establishment. Irrigation in box experiment ensured adequate opportunity for water uptake by germinating seeds and water loss from the germinating seedlings was not excessive since inadequate moisture hinders germination and establishment. The need for soil seed contact is to assist moisture movement from the soil to the seed. This has long been recognized and is the basis for the usual recommendation that seedbeds should be fine and firm. In this study the seedbed were pressed down with the sole of the foot to ensure this contact because as seed/soil contact become poorer, the rate of water absorption by the seed and the rate of seed germination become slower.

Under Kabete conditions, complete germination occurs in about 10 days after sowing scarified Quartin seed. Hard seed coat is an adaptive feature in legumes, which in nature prevent the possible loss of all sown seeds if one germination event is followed by adverse conditions in areas of unreliable rainfall. (Boonman, 1977) germination is delayed by the impermeability of the seed coat. Dormancy caused by hard seed coat must be broken if germination and establishment are to be rapid and uniform. Differences observed between seed germination in controlled condition and plant field establishment were mainly due to water stress in the field, which led to poor seed germination and seedling mortality in the field experiment. For this reason, it is not good to practice dry seeding at Kabete in clover if maximum establishment is to be expected.

The Emergence percent was highest under controlled moisture condition compared to field trial. The choice of sowing rate is determined by such factors as number of seeds per kilogram, seed quality, level of seed-bed preparation, slope, climatic risks, growth habit and the extent of weed problem (Kahurananga, and Tseley, 1984). High seed rate is not necessary for clovers as they will thicken up quickly from their fillers and lateral branches ensuring quick ground cover, hence reducing the risk of soil erosion and weed competition.

Plant height

The mean plant height increased with time, the plant height showing no significant differences (P<0.05) at 50% flowering period.

In the field experiment, the plant height growth rate was not significant ($P \leq 0.05$) among the establishment. Between stage 1 and early stage 2 there was no noticeable response to fertilizer when height was generally below 20cm. Plants in all the experiments had attained maximum height by 120days after planting indicated by the apical meristem developing into an inflorescent after splitting into two sister branches. Plant height in the field experiment did not attain normal Quartin clover's height. This could be attributed to soil moisture stress. Plants in the field were apparently more horizontal (Fig.13) with comparatively short apical shoot (about 20cm) compared to the average height of 50 –60 cm.

Total number of leaves

On the premise that air temperature is the most important determinant of leaf production in these experiments the number of leaves per plant increased rapidly initially and then more slowly or decreased. The average number of leaves per plant at the end of the vegetative growth phase was 171, 167, and 232 in the field establishment, 209, 205 and 212 in the box plot establishment and 194,187 and 228 in the green house in the upper, middle and lower slant respectively. Terrain treatments had no significant ($P \leq 0.05$) effect leaf number. The middle slant terrain had the least number of leaves in all the establishment treatments. These plants were compact with very short internodes in both vertical and lateral branches. The leaf petioles were also relatively short.

Number of primary branches

The number of main stem nodes and branches per plant were observed and recorded after every 14days. The rate of leaf appearance is determined by the number of nodes and branches, from which the leaves develop. Main stem nodes are the plants basic morphological unit on which branches develop and are supported. Land slant did not significantly affect the number of main stem branches. Branching occurred after the appearance of the third trifoliate leaf on the main stem node close to the cotyledon leaf and progressed bilaterally. Land slant treatment did not have significant ($P \leq 0.05$) effect on number of main stem branches per plant (Appendix 9.5). The reduced number of primary branches in field plots could have been due to soil moisture stress that may have contributed to reduced production of branches.

Percent ground cover (as indicated by WHO growth rating)

According to appendix 9.6, plant cover tend on the overall almost followed a sigmoid pattern. Number 1 -9 was used here only as index, increased plant cover occurred in the early stages of growth (between SI 1 - SI 6) as shown in table 3. In the field trials the normal growth was affected by periods of drought. A plateau occurred in stage3 and 4 of the plant growth cycle, a period at which plant cover was 100%. There after a decline was experienced in the late fourth stage. Lower leaves were shed as the upper leaves gradually dried up and the plants fell to the ground forming a mat.

Plant cover during seedling and early active growth stage is scanty and most of the photosynthetic active radiation (PAR) is not intercepted by the canopy hence slow dry matter accumulation. As percent plant cover increases, more incident PAR is intercepted which in turn causes the plant to grow and increase in dry matter yield, especially if moisture in the soil is not limiting.

### 8.2.2 Dry matter production (at 50% flowering)

Above ground dry matter produced at 50% flowering was 53.10, 46.05, and 38.38 g $plant^{-1}$ in the lower middle and upper slant terrain respectively. The differences in above ground dry matter are attributed to soil fertility and moisture differences. The dry matter (DM) was significantly ($P \leq 0.05$) among all treatments. Treatment effect on dry matter were analyzed statistically (ANOVA, see Appendix 9.2) for a typical output. Land gradient showed a significant ($P \leq 0.05$) difference in DM production. The lower slant had significantly ($P \leq 0.05$) higher DM than the middle and the upper slants. This may be attributed to increased soil moisture and fertility compared to the upper and middle slant.

These results indicate that soil moisture content and fertility are the limiting factors to clover growth and development as defined by Masaya and white, (1995). They stated that crop development refers to changes in the organ formation and is manifested as the onset or termination of different phases of a plants life cycle (i. e germination, flowering, seed growth, senescence and maturity). Above ground dry matter in those experiments was analyzed at 50% flowering because it is the recommended time for harvesting clover for fodder or hay. Dry matter production is proportional to the total amount of radiation (PAR) that is intercepted by the foliage and the efficiency with which it is converted to dry matter by green leaves. The total radiation incident on the canopy varies between locations and seasons and within seasons in a given location.

### 8.2.3 Seed yield

The differences in seed yield (tones per hectare) among the three treatments may be explained by differences in the number of seeds per plant and seed weight. Larger plants may have produced either more inflorescent plant$^{-1}$ and/or more seeds per inflorescent. Average monthly air temperature during reproductive phase was very high ($24.4^0$C and $27.6^0$C) in January and February 2007 respectively. This condition adversely affected seed filling in the field hence reducing productivity. There was a significant ($p \leq 0.05$) difference between terrain treatments.

The variation in environmental factors especially rainfall distribution, air temperature and relative humidity and land slant had adverse effect on seed yield. This seed yield in the lower slant terrain was significantly ($P \leq 0.05$) higher than the middle and upper partition. This difference could be attributed to soil moisture content and poor establishment of plant stand because some plants in the upper and middle slant terrain wilted and died during the drought periods. Total evaporation was also very high towards maturation stage. Heavy rains during the maturation stage caused the plants to rejuvenate hence extending the growing season. This change of weather caused Quartin clover to behave as a biennial with unsynchronized seed production, which made harvesting a very difficult and expensive task.

## 8.3 Mineral micronutrients density in Quartin clover

### 8.3.1 Mineral micronutrients density in Quartin clover plant tissues in relation to the soil status

Iron was the most abundant mineral micronutrients in the three terrain levels compared to all the other elements. The annual African clover absorbed this mineral nutrient from the soil and accumulated it in both the herbage and the seed tissues, which showed to be very rich in iron. Iron compounds are important in nutrition and iron is a requirement in animals and is biologically significant (Cole and Haresigh, 1985). This is because it is an essential component of hemoglobin, a red oxygen-carrying pigment of the red blood cells of vertebrates and muscle pigment myoglobin, Some body enzymes also have a composition, which include iron (Tadesse *et al*,. 1991). Feeding animals with Quartin clover would improve their health and avoid deficiency of iron which causes anemia.

Manganese is the 2$^{nd}$ most abundant mineral micronutrients in Kabete soils. There is a negative correlation between the Manganese concentration in the soil and in plant tissues. The terrain level with the highest concentration of Manganese in the soil has comparatively low concentration in the plant tissue. However the herbage and seed tissues contain considerably high levels of Manganese. This can be used to explain the fact that Manganese has been shown experimentally to be necessary for normal skeletal development in sheep but deficiencies have not been found under grazing conditions (Charles, 1983). As little as 0.5mg/kg of dietary dry matter is sufficient to maintain good growth rate and feed gain ratio in pigs from birth to 90kg live-weight (Fraser and Stamp 1987). Manganese compounds are less toxic than those of other widespread metals such as iron, nickel and copper compounds. However manganese is toxic in excess (Pohanish, 2006) for nearly all organisms living in the presence of oxygen use it to deal with the toxic effects of superoxide, formed from by the 1-electron reduction of dioxygen (Meco *et al*., 1994).

Iodine concentration could not be detected by the XRF spectrometer because it was at low detection limit (less than 0.05 ppm).

Zinc concentration in Quartin clover tissues at the three terrain levels was more than 50µ/g which is a clear indication that it is rich in Zinc. Since Zinc is present in all animal tissues and is a component of a number of enzymes, it is required for normal growth and appetite and the functioning of the testes is even more sensitive to deficiencies (Rook &Thomas1983). Zinc deficiency is characterized by growth retardation, loss of appetite, and impaired immune function. In more severe cases, zinc deficiency causes hair loss, diarrhea, delayed sexual maturation, impotence, hypogonadism in males, and eye and skin lesions (Maret Sandstead, 2006, Prasad, 2004). Weight loss, delayed healing of wounds, taste abnormalities, and mental lethargy can also occur but these are unlikely in grazing animals (Rook &Thomas1983) where grazing land has both grasses and forage legumes growing together. Zero grazing animals which in most cases are fed with Napier grass alone are at a risk of Zinc deficiencies. This problem can be alleviated by introducing high quality forage legumes such as Quartin clover into small holder farming systems.

The concentration of Copper in Quartin clover is approximately 25 µ/g which is half that of Zinc but far much more than that of Cobalt, Selenium and Molebdenum. Copper is an essential trace element in plants and animals, but not some microorganisms (Bonham, et al., 2002). It is needed for quite a wide variety of body functions where its deficiency is particularly indicated by in-coordination in newborns lambs and by anemia (Charles, 1983; Fraser and Stamp 1987) and poor growth in adults. A minimum dietary value for healthy growth in rabbits has been reported to be at least 3 ppm in the diet. However, higher concentrations of copper (100 ppm, 200 ppm, or 500 ppm) in the diet of rabbits may favorably influence feed conversion efficiency, growth rates, and carcass dressing percentages (Ayyat et al., 1995). Feeding animals with trifolium quartiniunum cv. Quartin clover which is rich in Copper can be can satisfy hidden hunger since Copper is essential in enzymes required for heart function, bone formation, energy metabolism, elastin synthesis, normal hair growth and red blood cell formation. (Encyclopaedia of Food Science and Food Tech., 1993).

Although soils at Kabete field station has considerable amount of Cobalt, very small amounts were absorbed and retained by the plant. The results show that the highest concentration of 5.83µ/g Cobalt was recorded as low detection mineral by the machine. Research has shown that luminal flora do not have any store of cobalt available and so daily intake is necessary (Charles, 1983; Nickerson, 1978). This is because Cobalt is an essential component of Vitamin $B_{12}$ which is manufactured by rumen micro flora. A deficiency leads to depression of all productive functions; perhaps most notably stunt growth, anemia and stillborn lambs.

There was very low concentration of Selenium and Molybdenum in both the soil and the in the plant tissues. Selenium is one of the elements needed in trace amounts in the animal and human diet. Selenium is important for animal muscular development and when deficient leads to degeneration of muscles, particularly of the hindquarters and arthritis (Stone *et al.,* 1997). It is in suckling lambs (when muscle development is at the peak) that is the most susceptible to this condition. Selenium is a requirement for cattle while the nutritional value of all plant food depends on the soil in which it was grown, the selenium content of plants seems particularly sensitive to soil concentrations (Charles, 1983). For this reason, most of the early research on selenium focused on diseases in sheep, cattle, turkeys, and pigs which involved low soil concentrations of selenium and insufficient amounts of selenium in the forage plants eaten by these animals. It is important to remember that the selenium content of food is highly variable because it depends so heavily on soil conditions. While soil conditions affect plant foods most directly, they also affect animal foods, since most animals depend upon plants for their diet.

Molybdenum is an essential trace element for virtually all life forms as it plays a complex role in animal growth and development. It functions as a cofactor for a number of enzymes that catalyze important chemical transformations in the global carbon, nitrogen, and sulfur cycles. Thus, molybdenum-dependent enzymes are not only required for human health, but also for the health of our ecosystem (Lide, ed. (2005). It is good to feed animals with feeds that contain small quantities of Molybdenum because Excess dietary molybdenum has been found to result in copper deficiency in grazing animals (ruminants). In ruminants, the formation of compounds containing sulfur and molybdenum, known as thiomolybdates, appears to prevent the absorption of copper (Jane Higdon, 2001). Small quantities are beneficial. Deficient diet encourages excessive copper storage with the associated risks mentioned above. High levels of molybdenum cause scouring and induce copper deficiency. The balance between molybdenum and copper is also affected by intake of sulfate with high levels increasing the danger of molybdenum toxicity (Nickerson, 1976).

### 8.3.2 Feeding Quality

Feeding quality has been defined as the amount of nutrient material that an animal can obtain from a feed in the shortest time possible (Encyclopedia of food Technology and Nutrition 1993). Forage quality can be measured in diverse ways (e.g. chemical analysis of the feed, consideration of the fibre content of the feed, the extent and the rate of digestibility, animal intake which is closely associated with live weight gain and its energy content as an important animal requirement (Hetzel, and Maberly, 1986). In general, plant tissue reflects soil deficiencies. Some of these deficiencies can be corrected in the forage by fertilizer application. Animals rarely suffer from complete lack of the minerals they require but particular deficiencies resulting from forage materials with low mineral content are common (Kahuranaga *et al*,. 1984). Most legumes are rich in calcium, copper, potassium and magnesium.

The plant and animals requirement for many minerals differ considerably. For example, Phosphorous is limiting to plant growth at much lower levels that that required by animals. Thus major animal disorders and even death may occur in pastures whose soil has amounts of phosphorous satisfactory for vegetative growth. Problems of this type can be overcome by use of salts and mineral licks to meet the livestock requirement especially when the deficient mineral is Iodine, Cobalt, or Calcium.

## 8.4 Effects of Phosphorus on Accumulation of mineral micronutrients in Quartin clover

Herbage production from forage legumes is influenced much more in terms of both quality and quantity by environmental factors such as nutrient status of the soil, climate and the management practices, than is the grain from cereal crops. Most important of all in the case of our forage crops, we have option of harvesting at a range of different times which is not possible in the case of grain crop production

Rate of phosphate applied at planting time leads to development of the herbage, which provides necessary photo-assimilates thus enhancing nodulation and BNF (Jutzi and Haque, 1984). Legumes use available soil nitrogen before nodule formation and fixing nitrogen symbiotically ( Heichel et al.,1984a). Fertilizer application increased dry matter yield, leaf nitrogen and phosphorous level of runner bean (Kahuro, 1990). Reneau et al., (1983) working on sorghum reported that phosphorus fertilizer increased nitrogen concentration sorghum. Application of phosphorous has been shown to increase dry matter yield, percent phosphorus of pasture legumes and nitrogen in pasture legumes (Muthoni, 2000). Phosphorus has been shown to increase dry matter yield of annual clover (Haque and Lupwayi, 1998, 1999; Mugwira et al., 1997; Haque and Mugwira , 1991; Kahurananga,1991; Kong et al., 1993; Akundabweni, 1984a, 1984b). In the current study, it was found that application of phosphorous affected uptake and accumulation mineral micronutrients in annual African clover differently as shown in the following figures

Annual African clover accumulated high concentration of iron in its tissues. The highest concentration at week 8 of growth at both 50kgha$^{-1}$ Application of phosphorous has been shown to increase Iron concentration in the tissues through enhanced root and herbage tissues development ;dry matter (Haque and Lapwayi, 1998; Kong et al., 1993). Ion of phosphorus at 60kgha$^{-1}$ negatively affected the accumulation of Fe in this clover since it affected the minerals availability to plants. Manganese concentration in Quartin clover was almost constant throughout the growth period regardless of the level of phosphate.

The concentration of Copper in Quartin clover was between 12.37 to 21.83 µ/g and 15.73 to 23.37µ/g at 0kg $P_20_5$ and 50kg $P_20_5$ respectively. The concentration of copper increased gradually with increased in phosphate levels.

Concentration of Iodine was the high at 30, 50 and 60 kgha$^{-1}$ $P_20_5$during the early seedling stage but declined as the clover grew older. This is because Quartin clover experience rapid growth with elongation of internodes and cellulose hardening in the stem and the internodes hence reduction of concentration of micro-elements in weight per weight

### 8.5 Conclusions and Recommendations

#### 8.5.1 Conclusions

1. Shortage of water can cause major losses in yield because when the amount of soil moisture in a locality is insufficient, crop growth is reduced since the crop may not respond to fertilizer addition if native fertilizer is adequate to produce the crop yield permitted by the moisture regime. In trying to solve these problems, timely planting and/or frequent irrigation is necessary to maximize yield, fast growth rate hence ability to produce high volumes of herbage within a short time. The terrain treatment had significant difference ($P \leq 0.05$) in stubble weight, seed and dry matter yield as shown in appendix 9.1 and 9.2 output tables. I therefore reject the first null hypothesis and state that there is difference in performance of Quartin clover due to terrain levels.

2. The results on accumulation of mineral micro nutrient in Quartin clover showed that there were differences in concentration of mineral micro nutrients between Quartin clovers seed and seedlings e.g seed has an average of 0.855ppm selenium while seedling have an average of 3.6 ppm. The mineral micronutrients accumulation in Quartin clover varied between the plant tissues and the seed. I therefore reject the hypothesis second hypothesis that Quartin clover remains with similar level of mineral micronutrient in seed and seedlings and state that it accumulates them differently in seeds and seedlings.

3. Phosphorous fertilizer is of crucial importance in post establishment, growth and development of Quartin clover, as well as the nutritive quality of the fodder. The highest copper accumulation was during week 8 of 50kg/ha $P_20_5$ while the lowest was during week 2 of 60kg/ha $P_20_{5.}$ The concentration of molybdenum was highest during week 2 of 50kg/ha $P_20_5$ while the lowest was during week 2 of 0kg/ha $P_20_5$ and week 6 of 30kg/ha $P_20_{5.}$ Selenium was highest at week 2 of 60kg/ha $P_20_5$ and lowest at week 6 of 0kg/ha $P_20_{5.}$ All the other mineral micronutrients concentration in the herbage varied considerably with phosphate application. I therefore reject the third null hypothesis and conclude that mineral

micronutrients accumulation in Quartin clover varied with different levels of phosphate fertilizer

4. The field establishment and box plot establishments had significant ($P \leq 0.005$) differences stubble weight and dry matter yield among terrain level treatments. I therefore reject the fourth Null hypothesis and conclude that different establishments of Quartin clover gave different herbage yield.

### 8.5.2 Recommendations

Uniformity in heading date is a primary requirement. In order to combat synchrony constraint, generic purity of the seed is to be observed if improved husbandry is not to be wasted (i.e. irrigation, plant density and proper nutrition).

High seed rate is not necessary for clover since as they will thicken up quickly from their tillers and/or lateral branches ensuring quick ground cover hence reducing the risk of water loss through evaporation and soil erosion through surface run off.

Further study should be carried out to determine the most effective method of scarification of clover seed for optimum germination and establishment of the stand.

Intercropping Quartin clover with cereals such as wheat, barley and short millet varieties needs to be investigated as an integrated nutrient management (INM), which may be an organic resource as a promising entry point into small holder systems,

## REFERENCES

**Abrams CK, Siram SM, Galsim C, et al., 1992.** Selenium deficiency in long-term total parenteral nutrition. Nutr Clin Pract 1992 7:175-178. 1992.

**Akundabweni, L.S; Lazier, J.R and Lamme, L. 1991.** Comparative growth of some African clovers planted at different times. Tropical grasslands 25:358-364.

**Akundabwen, L.S. and Njuguna F. 1984.** Seed production of some annual clovers at Sola in Ethiopia and Rabeta in Kenya. Tropical grosslands in press.

**Akundabweni L.S. 1984.** Nature cloves of Ethiopia highlandsss. The background companions ICCA Newsletter 3(1/5-6).

**Akundabweni L.S.M. 1984.** African clover- the backwood champions. ILCA Newsletter. ILCA, Addis Ababa. Ethiopia

**Akundabweni, L.S.M 1986.** Forage potential of some interactive Trifolium species in the Ethiopian highlandss proceedings of ILCA workshop 1985.

**Allan fraser and John T. Stamp, 1987.** Sheep husbandry and disease. 6$^{th}$ edition. Revised by J.M.M. Cunningham and John Stamp 1997.

**Andrew C.S, 1976.** Effects of calcium, PH and nitrogen and chemical composition of some tropical and temperate pasture legumes I nodulation and growth. Aug. Jan. Agric. Res 27:611-623.

**Ayyat M.S., Marai I.F.M., Alazab A.M. (1995).** "Copper-Protein Nutrition of New Zealand White Rabbits under Egyptian Conditions". *World Rabbit Science* **3**: 113–118.

**Badmaev V, Muhammed M, Passwater RA.1996.** Selenium: a quest for better understanding. Alt Ther 1996;2(4):59-67. 1996.

**Benka S.G., Lubkini G.B., 1995**. X-rays 100 years later. Physics today, special issue: pp 25

**Bogdan, A.V. 1968.** Indegenous clovers of Kenya East African agric. J. 22:40- 45.

**Bonham, M. *et al.* (2002).** "The immune system as a physiological indicator of marginal copper status?". *British Journal of Nutrition* **87** (5): 393–403.

**Boonman, J. G. 1993.** East Africa's grasses and fodders: Their ecology and husbandry.

**Charles, A.B. 1983**. Sheep production in the tropics. Oxfond Tropical Handbook.

**Cole, D.J.A. and Haresign, W. 1985.** Recent developments in pig production.

**Deloichie C.C. 1977.** Energy relationship in the global nitrogen fixation. Ambio, 6:106-111.

**Desbeiz, A., R. Mathews, B. Tripathi. And J. Ellis-Jones, 2004.** Perceptions and assessment of soil fertility by farmers in the mid-hill of Nepal. Agric. Ecos. Environ., 103:191-206.

**Diplock A.T 1992**. Selenium, antioxidant nutritions, and human diseases. Biol Trac Elem Res. 1992;33:155-156. 1992.

**Donahue R.L., Miller R.W and Sickluna J.C (1983);** An Introduction to Soils and Plant Growth. 5th Ed. Prentice Hall Inc. Engel woods Cliffs. New Jersey 07632. 294-342.

*Earth Sci.*, **2**,129-140.

**Encyclopaedia of Food Science and Food Technology and Nutrition. (**1993); MacraiR. Robinson R. K. Sadler M. J. (Eds). Minerals – Their Dietary Importance. Vol. **5**.

**Fujita, K., K.C Ofusu- Budu, and S. Ogata. 1992.** Biologic nitrogen fixation in mixed legume cereal cropping systems. Plant and soil 141: 155- 175.

**Fleming, K.L., D.G. Westfall, D.W. Weins, L.E. Rothe, J.E. Cipra and D.F. Heerman 1999**. Evaluating farmers Development Management Maps for precision farming. In Robert, P.C. and R.H. Rust (Eds.). Proceeding of 4th International Conference on Precision Agriculture.moisture stress in two Ethiopian highlandss soils. Plant and soil, 133:271-279.

Friedericks, J.B., C. Hagedorn and R.B. Beneau, 1991. Evaluation ofAffrican annual clover to

**Gachene, C.K.K, Jaruis N.J. Linner, H and Mbuvi, J.P 1997.** Soil erosion efforts on soil properties in highlandss areas of central Kenya. Soil Sci. Soc AM. J61, 559 - 564

**Gachene, C.K.K., M. Makau and R. Haru. 1997;** soil moisture extraction by different legume cover crops in participatory technology development for soil management by smallholder in Kenya. special publication of soil management and legume research network projects

**Gatari J.M. 2006.** Studies of atmospheric acrosols and development of energy dispersive X-ray florescent spectrometer in Kenya.

**Giller, K.E., C.D.E. Rowe, Ridder de Nico and H. van Keulen, 2005.** Resource use dynamics and interactions in the tropics. Scaling up dynamics and interactions in the tropics. Agric. Sys.,(in Press).

**Grant, D., Toft, K.G., Martinsen, I. and Atzpodien, E.** 1997: Tissue distribution and general safety of MnDPDP in male beagle dogs, with or without total common bile duct obstruction. *Acta Radiol.* **38**(4 Pt. 2): 732-739, 1997.

**Haque, I.; Lupwayi, N.Z. 2000.** Nitrogenfixation by annual forage legumes and its contribution to succeeding wheet in Ethiopian highlandsss. Journal; of plant nutrition (USA). V 23(7). P 963-997

**Hetzel, B.S. Maberly G.F. (1986);** Iodine In: Merrz W. (Ed.) Trace Elements in Human and Animal Nutrition Vol.**2** Academic Press. New York 139-208.

**Institute of Medicine, Food and Nutrition Board 2001.** Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, DC: National Academy Press, 2001.

**Jaetzoldt, R and Schmidt, H. 1983.** Farm management handbook for Kenya national conditions and farm management information part C East Kenya ministry of agriculture, Nairobi Onim, **J.F.M., Mathura, K. Otieno, and H.A Fitzbugh 1990**; Soil fertility changes and response of maize and beans on green manure of leucaena, sesbania and pigeon pea Agroforestry system 12:192-215.

**Jutzi , S.C.Haque, I 1985.** The effects of P and N/P fertilizer on the growth, nodulation ans seed of three African clovers on a P-deficient Vertisols. Welte, E (Ed.); Szabolcs,I. (ed.) International Sientific Centre of Fertilizer, Belgrade(Yugoslavia) Hungarian academy of Science, Budapest. Preceedings Volume 2.p. 423-426

**Jane Higdon, 2002.** PhD theses,Linus Pauling Oregon state university

**Kabata A.P. and Pendias H. (1984);** Trace Elements in Soils and Plants. CRC Press, Boca Raton. USA. 69-233.

**Kahurananga, J. Akundabweni, L.S and Jutzi S; 1986.** Collection and preliminary forage education of some trifolium species in Kategile J.A (eds.) pasture improvement research in East and Southern Africa, proceeding of a workshop held in Harare Zimbabwe, 17-21, Sept 1984. 1DRC (International Development Research Centre) Ottawa Canada pp 247- 259.

**Kahurananga, J.C: 1984.** Intercropping trifolium spp in wheat and its suitability for small holder farmer's condition of the Ethiopian highlandss proceedings of ILCA 1988.

**Kahurananga, J and Tseley, A 1984.** Preliminary assessment of some annual trifolium species for hay production Tropical Grasslands 8(4): 215-217.

**Kahurananga, J, and Tseley A. 1991.** Variations in flowering time dry matters and seed yield among annual trifolium species. Tropical grasslands 25:20-25.

**Kamal, M. Ibrahim 1989**. An illustrated manual of Kenya legumes. National Agricultural Research Centre, Kitale.

**Karydas, A.G., Zarkadas, A., Kyriakis, A., Pantazis, J., Huber, A., Redus, R., Potiriades, C., Paradelis, T. 2003.** Improvement of peak to background ratio in PIXE and XRF method, using small thickness thin Si- PIN detectors, X-Ray Spectrometry, Vol. 32. No. 2 p. 93-105.

**Laubuza, T.P. 1974.** Food for thought.

**Lide, D. R., ed. 2005.** CRC Hardbook of chemistry and Physics ($86^{th}$ ed.) Boca Raton (FL): CRC Press. ISBN 0-8493-0486-5

**Mannetje L.T 1987. Harry stobbs memorial lecture, 1994.** Potential and prospects opf legumes based pastures in tropics. Tropical grasslands, 31:81-94.

**Mannetje, L.T. 1964.** The use of some African Clovers as pasture legumes in Queensland Australia. Aust. J. Agric and Animal husbandry.

**Maret W, Sandstead, H. H. 2006.** Zinc requirements and the risks and benefits of zinc supplementation. J Trace Elem Med Biol 2006;20:3-18.

**t'Mannetje, L.T, O'Eonnor, K.F and Burt, R.L. 1980.** The use and a daptation of pastures and fodder legumes. In: summerfield, R.J and Bunting, att. (edsd). Advanced in legume science. Royal Botanical Gardens ken. Pp 537-551.

**Mburu, M.M. 1996.** Effect of irrigation, fertilizer nitrogen, and planting density on bean (phaseolus vulgaris L.) yield under different climatic conditions. University Theses.

**McWilliams, J.R 1978.** Response of pasture plants to temperature. Plant relation in pasture wedge and Bolls LTD, Australia.

**Meco, G., Bonifati, V., Vanacore, N. and Fabrizio, E. 1994:** Parkinsonism after chronic exposure to the fungicide maneb (manganese ethylene-bis-dithiocarbamate). *Scand. J. Work Environ. Health* **20**(4): 301-305, 1994.

**Miller J.R, Julian B. F, Benson A.K, 1988.** Effect of Iodine on growth and development in lambs and calves

**Mineral Research and Development (Charlotte, NC) 2003:** Material Safety Data Sheet: Manganese (II) Nitrate Solution (Jan. 30, 2003) 8 pp.

**Mose, L.O., H.O. Nyangito and L.G. Mogenieri, 1996.** An analysis of the social-economic factors that influence chemical fertilizer use among small holder maize producers in western Kenya. A paper presented at the 5$^{th}$ Eastern and Southern Africa region maize conference held at Arusha Tanzania from 3$^{rd}$ to 7$^{th}$ June 1996.

**Mosi, A.K and Butterworth M.H. 1983.** Use of Trifolium tembense to enhance crop resident utilization by luminants. KCA Newsletter 2:5-6.

**Murage, E.W., N.K. Karanja, P.C. Smithson and P.L. woomer, 2000.** Diagnostic indicators of soil quality in productive and non-productive small holder fields of Kenya's Central Highlandsss. Agric. Ecoc. Envirn., 19:1-8

**Muthoni, 2005.** The effects of Phosphorous of the productivitu of trifoliu quartinianum in Kabete Nitosols

**National Research Council 1983.** Selenium in nutrition. Revised edition. Board on Agriculture, Committee on Animal Nutrition, National Academy of Sciences Press, Washington, DC, 1983.

**Nickerson, J.T.R. 1976.** Elementary food Science

**Njarui D.M.G. and F.P. Wandera 1997;** Effects of intercropping pasture legumes with fodder grasses and maize on forage and maize grains yields in the semi arid Eastern Kenya. In participatory technology development for soil management by Small holder in Kenya special publication of soil mgt & legumes research network

**Nnandi, L.A., and I Haque, 1986;** Forage legumes- cereal systems improvement of soil fertility and agricultural production with special reference to sub-saharan Africa pp 330-362 in Hargue et al 9eds) (19986). Potential of forage legumes in farming systems of sub-Saharan Africa- ILCA, Addis Ababa, Ethiopia

**Normandin, L., et al., 2004.** Manganese distribution in the brain and neurobehavioral changes following inhalation exposure of rats to three chemical forms of manganese. *Neurotoxicology* **25**(3): 433-441, 2004.

**Norris, D.O. 1965.** Acid production by rhizobium urifying concept. Plants and soil 22:143-146.

**Olayiwole, M; Blatterworth, H.M; Sayers, A.R and Olorunju, s.A.S; 1986**. The effect of supplementing cereal straws with urea, Trifolium hay and noug meal on feed intake and weight gain of growing cross breed heifers, ILCA Bulletin 24:18-19.

**Pamo, ET and TC Mubetener, 1995;** Coperative performance of the establishment of some forage legumes in the western highlandsss zone of Cameroon in Rangelands in a sustainable biosphere proc. Of $5^{th}$ international rangeland congress vol. 1 428-429 salt city Utali, USA, July, 23-28

**Pohanish, R.P. (ed. 2006):** Manganese Nitrate. In, *Sittig's Handbook of Toxic and Hazardous Chemicals and Carcinogens, Fourth Ed.*, Vol. 2. Norwich, NY: Noyes Publications, William Andrew

**Prasad, A. S. 2004.** Zinc deficiency: its characterization and treatment. Met Ions Biol Syst 2004; 41:103-37.

**Prasad, L.K. 1995.** Vegetation dynamics of some pasture grasses in India in Rangelands in a sustainable biosphere pro.

**Raymond Frank, Peter Redman and Richard Waltham, 1986.** Forage conservation and feeding.

**Rook, J.A.F. and P.C. Thomas, 1983.** Nutrition physiology of farm animals

**Sanchez A.P., K.D. Shepherd, M.J. Soule, F.M. Place, R.J. Buresh and A.M.N. Lzac, 1997.** Soil replenishment in Africa. An investment in Natural resources capital. In: Replenishing soil fertility in Africa, SSSA Special publication No. 51

**Sanchez, P.A. 1976.** Properties and mgt. of soil in the tropics John Wiley and sons, London

**Sanginga, N., K Mulongo and M.J Swift. 1992.** Contribution of soil organisms to the sustainability and productivity of cropping systems in the tropics, agriculture ecosystems and environment,

**Skerman, P.J., DG Cameroon and F.rivers, 1998.** Tropical forage legumes (2nd ed)FAO, Rome.

**Smaling, E.M.A. and A Broun, 1996.** Soil fertility research in sub-saharan Africa: New dimension new challenges. Comm. Soil Sc. Plant Anal., 27:365-386.

**Solomon P.A., Norris G., Landis M. , Tolocka M.2001.** Chemical analysis method for atmospheric Aerosol components, in: Aerosol measurements principles, techniques and application,2nd Edition; Baron P.A., Willeke K.,(eds.). Jonh Wiley and sons inc., New York, USA;

**Stone J, Doube A, Dudson D, et al. 1997.** Inadequate calcium, folic acid, vitamin E, zinc, and selenium intake in rheumatoid arthritis patients: results of a dietary survey. Semin Arth Rheum 1997;27(3):180-185. 1997.

**Tabu, I.M., 2003.** Soil fertility niches, farmer perception and maize yield: A case for improved crop yield in Kabras division of western Kenya. PhD Thesis, Egerton University

**Titonell, P., B. Vanlauwe, P.A. Leffelaar, K.A. Shepherd and K.E. Giller, 2005**. Exploring diversity in soil fertility management in small holder farms in western Kenya. II. Within farm variability in resource allocation, nutrient flow and soil fertility status. Agric. Ecos. Envirn., (In Press)

**Tothill, J.C 1990.** The role of legumes in farming systems of subharan Africa. Proceeding of ICCA., P.C (1982). Tropical pasture Science Oxford University press. London pp. 98

**Underwood, E .J. (1999);** Trace Elements in Human and Animal Nutrition. Academic Press NY. 13-302.

**Verhagen, A. And J. Bouma, 1997.** Modelling soil variability. In: Pierce F. J. Saddler (Eds.). The site specific management for agricultural systems. ASSA-CSSA-SSSA, Madison,USA.

**Willis MS, Monaghan SA, Miller ML, McKenna RW, Perkins WD, Levinson BS, et al., 2005).** Zinc-induced copper deficiency: a report of three cases initially recognized on bone marrow examination. Am J Clin Pathol 2005;123:125-31.

**Wondafrash, 2000.** The effects of soil moisture days and soil types on the growth of four African Trifolum species Msc thesis, UON.

**Woomer, P.L Martin, A. Albrecht, A.Resek, D.V.S and Scharpenseel, H.W (1994).** The importance and management of soil organic matter on the Tropics pp 47-80.

**Zohary M. 1972.** Origin and evolution in the genus trifolium

**APPENDICES**

**Appendix 9.1 Analysis of variance Table for seed yield in Tons per hectare**

a) Field experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.000319 | 0.000106 | 0.08 | |
| Treatment (slants) | 2 | 0.04584 | 0.02292 | 16.85 | 0.003 |
| Residual | 6 | 0.00816 | 0 .00136 | | |
| Total | 11 | 0.054319 | | | |

b) Box experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.0006184 | 0.0002061 | 0.53 | |
| Treatment ( slants) | 2 | 0.006305 | 0.003152 | 8.07 | 0.020 |
| Residual | 6 | 0.002344 | 0.0003907 | | |
| Total | 11 | 0.009267 | | | |

c) Green house experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.0005321 | 0.0001642 | 0.34 | |
| Treatment (slants) | 2 | 6.564 | 2.1883 | 13.80 | 0.001 |
| Residual | 6 | 5.7065 | 0.1585 | | |
| Total | 11 | 12.271 | | | |

**Appendix 9.2 Analysis of variance Table for dry matter yield in tons per hectare**

a) Field experiment

| Source of variation | d.f. | s.s. | m.s.s. | var F pr. |
|---|---|---|---|---|
| Block | 3 | 15.718 | 5.239 | 0.65 |
| Treatment (slants) | 2 | 433.762 | 216.881 | 26.74 0.001 |
| Residual | 6 | 48.668 | 8.111 | |
| Total | 11 | 498.149 | | |

b) Box experiment

| Source of variation | d.f. | s.s. | m.s.s. | var F pr. |
|---|---|---|---|---|
| Block | 3 | 26.87 | 8.957 | 1.61 |
| Treatment (slants) | 2 | 451.599 | 225.799 | 40.68 0.001 |
| Residual | 6 | 33.305 | 5.551 | |
| Total | 11 | 511.773 | | |

**Appendix 9.3 Analysis of variance Table for dry stubble weight in tons per hectare**

Field experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.08541 | 0.02847 | 0.45 | |
| Treatment (slant) | 2 | 1.01386 | 0.50693 | 8.02 | 0.020 |
| Residual | 11 | 1.47841 | | | |

**Appendix 9.4 Analysis of variance Table for plant height**

a) Field experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 82.9 | 27.6 | 0.11 | |
| Treatment (slants) | 2 | 69.6 | 34.8 | 0.14 | 0.866 |
| Residual | 54 | 13066.1 | 242.0 | | |
| Total | 59 | 13218.5 | | | |

b) Box Experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 3036.8 | 1012.3 | 2.27 | |
| Treatment (slants) | 2 | 1050.7 | 175.1 | 0.39 | 0.883 |
| Residual | 30 | 58032.3 | 44.64 | | |
| Total | 35 | 62119.8 | | | |

**Appendix 9.5 Analysis of variance Table for main stem branches per plant**

a) Field Experiment

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.09 | 0.03 | 0.00 | |
| Treatment (slants) | 2 | 8.89 | 4.45 | 0.35 | 0.706 |
| Residual | 54 | 685.83 | 12.70 | | |
| Total | 59 | 694.81 | | | |

a) Box Experiment

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.36 | 0.12 | 0.00 | |
| Treatment (slants) | 2 | 9.75 | 4.88 | 0.14 | 0.870 |
| Residual | 54 | 179.65 | 34.81 | | |
| Total | 59 | 1889.76 | | | |

c) Green house experiment

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.36 | 0.12 | 0.00 | 1.000 |
| Treatment (slants) | 2 | 9.84 | 4.57 | 0.12 | 0.879 |
| Residual | 48 | 876.60 | | | |
| Total | 53 | 1889.54 | | | |

**Appendix 9.6 Analysis of variance Table for plant ground cover**

a) Field experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 2.133 | 0.711 | 0.13 | |
| Treatment (slants) | 2 | 75.60 | 37.800 | 6.84 | 0.002 |
| Residual | 54 | 298.267 | 5.523 | | |
| Total | 59 | 376.000 | | | |

b) Box experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.314 | 0.105 | 0.02 | |
| Treatment | 2 | 125.943 | 20.990 | 4.48 | 0.995 |
| Residual | 54 | 524.800 | 4.686 | | |
| Total | 59 | 656.543 | | | |

c) Green house experiment

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 4.533 | 1.511 | 0.26 | |
| Treatment | 2 | 14.400 | 7.200 | 1.23 | 0.856 |
| Residual | 48 | 281.60 | 5.867 | | |
| Total | 53 | 301.660 | | | |

**Appendix 9.7 Analysis of variance Table stubble weight in the field establishment**

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.015548 | 0.005183 | 0.60 | |
| Treatment (fertilizer) | 3 | 0.287441 | 0.143720 | 16.55 | 0.004 |
| Residual | 6 | 0.052109 | 0.008685 | | |
| Total | 11 | 0.355097 | | | |

**Appendix 9.8 Analysis of Variance for Leaf number in the field establishment**

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 1246 | 415 | 0.26 | |
| Treatment (fertilizer) | 3 | 30372 | 15186 | 0.73 | 0.485 |
| Residual | 54 | 1119169 | 20725 | | |
| Total | 60 | 1150787 | | | |

**Appendix 9.9 Analysis of variance table for ground cover in field establishment**

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 0.314 | 0.015 | 0.03 | |
| Treatment (fertilizer) | 3 | 125.943 | 20.990 | 5.15 | 0.001 |
| Residual | 130 | 5330.286 | 4.079 | | |
| Total | 136 | 656.543 | | | |

**Appendix 10.0 Analysis of variance Table for nodules formation**

| Source of variation | d.f. | s.s. | m.s.s. | var | F pr. |
|---|---|---|---|---|---|
| Block | 3 | 486.5 | 1622 | 0.33 | |
| Treatment (fertilizer) | 3 | 187561 | 31260 | 0.29 | 0.001 |
| Residual | 130 | 646166 | 4971 | | |
| Total | 136 | 838592 | | | |

**Appendix 11.0 Table 4.2 Rainfall (mm) at the experimental site for the entire study period**

| RAINFALL (MM) 2006/2007 | | | | |
|---|---|---|---|---|
| **Month** | **Total** | **Average** | **Rainy days** | **Total evaporation** |
| January | 185.8 | 5.99 | 5 | * |
| February | 31.9 | 1.14 | 4 | * |
| March | 83.9 | 2.71 | 4 | * |
| April | 429.8 | 14.33 | 23 | * |
| May | 170.1 | 5.49 | 6 | 47.9 |
| June | 10.44 | 0.35 | 6 | 68.4 |
| July | 10.20 | 0.33 | 3 | 101.2 |
| August | 0.2 | Trace | 2 | 97.7 |
| September | 16.1 | 0.54 | 7 | 129.1 |
| October | 82.0 | 2.65 | 13 | 120.6 |
| November | 118.31 | 3.94 | 20 | 113.4 |
| December | 58.1 | 1.87 | 9 | 136.1 |
| January | 77.8 | 2.51 | 4 | 173.3 |
| February | 45.7 | 1.6 | 2 | 174.2 |
| March | 91.0 | 2.9 | 5 | * |

**Appendix 10.1 Table 4.3 Average air temperatures at the experimental site for 2006/2007**

| **Average air temperature ($^0$C) 2006/2007** | | | |
|---|---|---|---|
| **Month** | **Maximum** | **Minimum** | **Lowest grass minimum** |
| January | 24.5 | 14.3 | 7.9 |
| February | 24.1 | 14.3 | 9.1 |
| March | 25.2 | 15.3 | 8.4 |
| April | 23.5 | 14.9 | 10.7 |
| May | 23.0 | 14.0 | 8.4 |
| June | 18.3 | 11.5 | 5.8 |
| July | 22.6 | 10.0 | 4.2 |
| August | 22.3 | 11.0 | 5 |
| September | 24.5 | 12.5 | 5.5 |
| October | 23.8 | 13.9 | 5.4 |
| November | 22.7 | 14.5 | 10.0 |
| December | 23.8 | 14.4 | 8.5 |
| January | 25.4 | 14.3 | 7.1 |
| February | 27.6 | 13.9 | 6.5 |
| March | 20.6 | 14.0 | 5.8 |

**Appendix 10.2 Table 4.4 Average monthly relative humidity during the entire study period**

| Average relative humidity (%RH) 2006/2007 | | | |
|---|---|---|---|
| Month | Sunshine hours | %RH at 00600 | %RH at 01200 |
| January | * | 81 | 56 |
| February | * | 79 | 55 |
| March | * | 81 | 50 |
| April | * | 88 | 64 |
| May | 6.6 | 83 | 60 |
| June | 4.7 | 83 | 55 |
| July | 6.2 | 80 | 49 |
| August | 4.6 | 82 | 52 |
| September | 6.4 | 80 | 43 |
| October | 6.3 | 82 | 52 |
| November | 3.4 | 87 | 59 |
| December | 8.6 | 83 | 56 |
| January | 9.9 | 71 | 43 |
| February | 10.0 | 65 | 38 |

NB: % RH at noon was always lower than the earlier morning

**Appendix 10.3 Table 5.1 Accumulation of Biomass in Quartin clover seedlings**

| Sampling Intervals | Week 2 | Week 4 | Week 6 | Week 8 | Week 10 | Week 12 |
|---|---|---|---|---|---|---|
| Plant Height (Cm) | 7.2 | 10.3 | 14.3 | 15.5 | 17.5 | 22.8 |
| Branching (No) | 1.6 | 2.4 | 3.81 | 8.79 | 14.25 | 16.8 |
| Ground cover (%) | 3 | 5 | 7 | 9 | 9 | 9 |
| Leave Number (No) | 6.8 | 10.1 | 16.7 | 84.7 | 145.2 | 176.9 |
| Nodulation (No) | 0 | 122 | 178 | 216 | 223 | 230 |
| Dry matter Yield(Tons/Ha | 1.85 | 5.16 | 8.53 | 10.23 | 11.80 | 15.04 |
| Seed Yield (Tons/Ha) | 0 | 0 | 0 | 0 | 0 | 0.476 |

**Appendix 10.4 Table 4.5 Percent soil moisture content**

| | Jan | Feb | Mar | April | May | Jun | Jul | Aug |
|---|---|---|---|---|---|---|---|---|
| UST | 23.05 | 24.13 | 20.57 | 30.24 | 28.37 | 27.80 | 25.46 | 20.80 |
| MST | 22.90 | 20.36 | 20.24 | 26.08 | 31.24 | 27.50 | 24.84 | 21.78 |
| LST | 27.43 | 28.20 | 27.02 | 30.31 | 27.50 | 27.00 | 27.52 | 20.70 |

| | Sep | Oct | Nov | Dec | Jan | Feb | Mar | April |
|---|---|---|---|---|---|---|---|---|
| UST | 20.05 | 18.60 | 29.82 | 20.61 | 23.05 | 27.20 | 26.24 | 24.26 |
| MST | 21.10 | 18.64 | 28.76 | 23.37 | 25.84 | 28.06 | 27.15 | 20.52 |
| LST | 20.81 | 20.99 | 28.67 | 24.27 | 26.28 | 28.34 | 23.81 | 28.22 |