CHAPTER 1

1.0. INTRODUCTION

Sweetpotato (*Ipomoea batatas*, (L.) Lam), ranks as the world's seventh most important food crop, after wheat, rice, maize, Irish potato, barley and cassava (Gichuki, 2000). In Zambia, sweetpotato is the second most important root crop from cassava and has the potential to contribute significantly to food security as a source energy and vitamin A (Chiona *et al*, 2007). Micronutrient malnutrition affects more than half of the world population, with one third of the world population suffering from vitamin and mineral deficiencies (Welch and Graham, 2004). Iron deficiency is estimated to affect 3 billion people worldwide (Long *et al.*, 2004) and about 49% of the world's population is at risk for low zinc intake (Cichy *et al.*, 2005). Vitamin A deficiency on the other hand affects over 140 million under the age of five (*Biofortified Sweetpotato*, 2006). Micronutrient deficiencies are concentrated in semi-arid tropics, particularly in South and Southeast Asia and sub-Saharan Africa (Reddy *et al.*, 2005). Attempts have been made to alleviate these deficiencies by the of supplements and food fortification, but these strategies do not reach all those suffering deficiency and have not proven to be sustainable (Römheld, 1998). There are a number of reasons sweetpotatoes biofortified with iron and zinc could be a powerful tool in the fight against iron and zinc malnutrition. Sweetpotato is an important staple crop in areas in which iron and zinc deficiencies were a particular problem (Courtney, 2006). It is low in inhibitors (e.g., phytates) and high in promoters (e.g., ascorbic acid), so even a small increase in iron and zinc conce will impact positively in the health of consumers. Sweetpotatoes provide a large yield per area per unit of time, and are capable of yielding even in marginal conditions. This makes it an ideal sustainable crop for production in developing countries, where high population has decreased growth the amount of arable land per person and results the use of marginal land for food production (Woolfe, 1 2). While yields of sweetpotato were still low in many countries, it has been shown that there is tremendous potential for increasing yield by the introduction of clones and more efficient cultivating practices. Finally, sweetpotato provides two useful foods from the same plant; both the roots and shoot tips are used as a nutritious food for human and animal consumption (Woolfe, 1992). Presently little is known about the co iron and zinc in sweetpotato. A range of 0.59 ppm to 0.86 ppm (fresh weight) and a l l of 0.24 ppm (fresh weight) for iron and zinc, respectively, were given in Woolfe (1992). The USDA gives 0.61 ppm and 0.30 ppm for iron and zinc concentration, respectively (http:// www.nal. usdagov/fnic/food/search/). Furthermore, there is no published information on the pic range of iron and zinc concentration in sweetpotato.

A deficiency in Fe and Zn has specific health consequences, such as anemia, poor growth and development in children and low productivity in adults (Tryphone *et al*, 2007). Orange-fleshed sweetpotato varieties are rich in betacarotene that the body uses to produce vitamin A. Vitamin A deficiency weakens the immune system leaving them susceptible to diseases such as measles, malaria, and diarrhea (Anderson, 2007). To generate sufficient supply of micronutrients through diets mainly consisting of Sweetpotato, specific interventions in plant breeding are needed.

The objectives of this study were to characterise the agronomic parameters and to determine if there are genetic variations in micronutrient concentrations of orange-fleshed sweetpotato varieties grown under different environments.

CHAPTER 2

2.0. LITERATURE REVIEW

2.1. Genetics and breeding behavior of sweetpotato

Sweetpotato (*Ipomoea batatas* L. [Lam.]) is a dicotyledonous root crop and a member the family *Convulvulaceæ* (Woolfe, 1992). Its exact origin is unknown but the available evidence suggests southern Mexico as a likely place of origin (Gichuki, *et al.*, 2003). By weight, sweetpotato is the seventh most important food crop worldwide, after wheat, rice, maize, potato, barley and cassava (Woolfe, 1992). It is the only member of *Ipomoea* of major economic importance (Woolfe, 1992). China accounts for 84% of the world's sweetpotato production. The primary importance of sweetpotato is in poor regions of the world. It is the fourth most important food crop in developing tropical countries and is grown in most of the tropical and subtropical regions of the earth, where the vine, as well as the roots, is consumed by humans and livestock (Woolfe, 1992). While yields in the United States were about 12-13 t/ha, in tropical countries yields can be about 35-40 t/ha (Woolfe, 1992).

Sweetpotato is a highly heterozygous natural hexaploid (2n=6x=90). The sweetpotato genome is made up of ninety chromosomes and sweetpotato is the o known hexaploid. Most wild species are diploid; occasionally triploid or tetraploid examples are found in collections (Jones, *et al.,* 1986). Interspecific crosses are difficult to make in however, since it is a hexaploid organism and is so genetically diverse, there is extensive variability within the species available for exploitation by plant breeders. Genotypes differ in root flesh color, root skin color, in the size and shape of roots and leaves, the depth of rooting, the time to maturity, disease resistance, and in the texture of the flesh (Woolfe, 1992). It is not known, however, to what extent iron and zinc levels vary among genotypes.

The complicated nature of sweetpotato genetics makes them difficult for breeders to manipulate. Almost all traits are quantitatively inherited, and mass selection is used to rapidly aggregate desirable alleles (Jones, *et al.,* 1986). Sweetpotato is propagated asexually so any advances made in breeding can be passed on to the producer and consu without the need for achieving homozygosity.

There are a number of reasons sweetpotatoes biofortifi with iron and zinc could be a powerful tool in the fight against iron and zinc malnutrition. It is an important staple crop in areas in which iron and zinc deficiencies are a particular problem. It is low in inhibitors (e.g., phytates) and high in promoters (e.g., ascorbic acid), so even a small increase in iron and zinc concentration will contribute towards the health of the consumers.

2.2. Role of sweetpotato in household food security and nutrition

Among the root crops in the Zambia, the sweetpotato ranks first from the standpoint of area planted and production. It is an important source of carbohydrates and its storage roots have many uses. Sweetpotato has a large yield per area per unit of time, and is capable of yielding even in marginal conditions. This makes it an ideal sustainable crop for production developing countries, where population growth has decreased the amount of arable land per person and increased the use of marginal land for food production (Woolfe, 1992). While yields of sweetpotato were still low in many countries, it has been shown that there is tremendous potential for increasing yield by the introduction of clones and more efficient cultivating practices. Sweetpotato is also a dependable subsistence crop (Woolfe, 1992). It does not require high levels of input, and can grow and produce under relatively dry conditions, making irrigation less necessary. Also, sweetpotato does not "mature" as such and will continue growing as long as the environment allows, so a farmer is able to use all of an unusually long growing season, or produce a partial crop even in a season too short for other crops to mature in. This characteristic also makes it possible to produce o crops per year in some areas (Woolfe, 1992).

2.3. Ecological Requirements

Sweetpotato can be grown in different kinds of soil, but sandy loam reasonably high in organic matter with permeable sub-soil is ideal. Good drainage is also essential since the crop cannot withstand water logging. A soil pH of 5.6-6.6 is preferred for sweetpotato (Schultheis *et al*, 2005).

Regions with a rainfall ranging from 750 to 1000 mm per annum with about 500 mm falling during the growing season, is best for sweetpotato. The rest of the rain falling during non-growing season makes it relatively easy to propagate and maintain vine growth of cuttings that will be used as planting materials during the next season. Growth is best at temperatures above 24^{o}C. In general, sweetpotato needs relatively high temperature during the growing period (Bartolini. 1987).

2.4. Stability parameters

Genotype by environment (G x E) interaction refers to variation in response among genotypes, when evaluated in different environments (Dixon *et al.,* 1997). It is a routine occurrence in plant breeding programmes, which enables plant breeders to identify superior genotypes and locations that represent best production environments. Any genotype that is assessed without including its interaction with the environment is said to be incomplete and thus limits the accuracy of yield estimates. Therefore a significant portion of the resources of crop breeding and agronomy programme is devoted to determining this interaction through replicated multi-location trials.

According to Crossa (1990) multi-location trials have three main agricultural objectives which include a) accurate estimation and prediction of yie based on limited data, b) determination and prediction of yield stability and the pattern of response of genotypes or agronomic treatments across environments, and c) providing reliable guidelines for selecting best genotypes for planting in future years and at new sites. Plant breeders aim to cover a representative sample of spatial and temporal variation. Sometimes a breeder's ion environments in one year may have little relation with those experienced in the next, suggesting a need to test under many crop cycles, and or many locations. Environmental diversity permits identification of extreme environmental conditions that guarantee selection pressure from important stresses (Dixon *et al.*, 1997). Therefore G x E guides the breeder in deciding to aim for wide or specific adaptation, whether to conduct early generation select in stressed or stress-free environments, and whether to test a large number or fewer genotypes in multi-location trials.

In conducting G x E studies it is important that a breeder understands the optimal requirements for filed experimentation. Dixon and Nukenine (2000) determined the optimal number of replications, locations, or years for G X E studies in cassava, based on the expected variance of a genotype mean (V_x), which can be estimated using the formula:

$$V_x = s^2gy/y + s^2gl/l + s^2gly/ly + s^2e/rly.$$

They found out that V_x decreases as the number of replications, locations or years are increased. The authors suggest that the best option therefore, is to use the least number of replication in locations that will not jeopardize precision. Depending on the combination of number of replications and years, the critical point is generally attained when the number of location is between 3 and 5 for all the yield trials, representing the optimum number of locations required in cassava yield trials. Fewer than 3 locations will result in inaccurate selection for any of the yield trails, whereas more than 5 locations will only increase costs without any significant gain in precision. Having very few replications generally is not advisable. Therefore, 3 to 4 replications in each of 3 to 4 locations and 2 to 3 years should suffice for cassava yield evaluation (Dixon and Nukenine 2000).

2.5. Biotic constraints affecting sweetpotato production

Sweetpotato farmers in developing countries face several biotic and abiotic constraints that reduce crop productivity. The main biotic constraints to sweetpotato production include viruses, sweetpotato weevil and white fly. The lack of high quality planting material is a common problem for sweetpotato in developing countries where l seed production systems are virtually non-existent. In addition, soil fertility is declining in many developing countries, affecting the present and future productivity of this which is usually planted to a large extent in marginal areas (FoDiS information series, 20).

2.6. Iron and zinc in plants

As with humans and other animals, iron and zinc are essential for plant health and proper growth and development. Thus, plant foods are significant sources of iron and zinc for humans. Iron is a catalyst in chlorophyll formation, is a component of ferredoxin, and is present in several peroxidase, catalase, and cytochrome oxidase enzymes (Brady, 2002). Iron deficiency in plants is manifested as interveinal chlorosis on new leaves (Aquaah, 2002). Zinc promotes growth hormone biosynthesis, the formation of starch, and seed production and maturation (Brady, 2002). Plants that are deficient in zinc have reduced size and shortened internodes. Interveinal chlorosis may appear in young leaves, as is the case with iron deficiency (Aquaah, 2002).

Since iron and zinc are usually present in soil in adequate to excess ounts, deficiency is caused by their presence in an unavailable form rather than by their lack, and a plant can improve its iron and zinc uptake by using strategies that solubilize the iron and zinc present in the soil (Rengel, 2001). For the most part, plants acquire micronutrients by absorbing them from the soil solution; therefore, the availability of micronutrients to plants is closely related to the solubility of the forms in which they appear (Aquaah, 2002). Many factors such as pH, soil organic matter and fertilizer application influence the mineral contents of the soil and the available nutrient concentration. Lindsay and Norwell (1969) indicated that critical concentration of iron and zinc contents of soils are 4.5 mg/100g and 0.8 mg/100g, respect ly. The uptake efficiency of soil-grown plants may consist of increased capacity to solubilize non-available nutrient forms into forms that are available to the plant, and/or increased capacity to transport nutrients across the plasma membrane. However, it appears that increased conversion capacity is of greater importance for efficient uptake, especially for nutrients that are transported to roots by diffusion (Rengel, 2001).

2.7. Zinc Deficiency in Plants

It has been estimated that zinc deficiency is the most widespread micronutrient deficiency affecting production and quality of cereals, such as wheat, rice, and other crops (Courtney, 2006). Genotypes of plants vary widely in their tolerance of zinc deficient soils. Tolerance to zinc deficiency is termed "zinc efficiency," and defined as the ability of a genotype to grow and yield well in soils too deficient in available zinc for a standard cultivar (Yang and Römheld, 1999). Zinc enters the plant mainly via root absorption of Zn^{2+} from the soil solution. Because of the low zinc concentration in the soil solution, supply of zinc by mass flow is limited and diffusion is the major process by which zinc reaches the roots. Therefore, root morphology and vitality characteristics are crucial in how efficiently the plant explores for zinc in the soil. Less work has been done on understanding the mechanisms of uptake compared to iron uptake in higher plants; however, zinc uptake appears to be a function of transport across the plasma membrane, which is largely metabolism-dependent, and genetically controlled (Yang and Römheld, 1999). For example, zinc-efficient wheat genotypes release more phytosiderophores than do inefficient genotypes (Rengel, 2001). Phytosiderophores are released in graminaceous species under iron and zinc deficiency stress and are great ecological significance for acquisition of iron and presumably also of zinc. Phyto ores are defined as any of a class of chelate compounds, common in grasses that sequester iron (Römheld, 2001). The speculated mechanisms of zinc uptake in the plant include thermodynamic transport of zinc, driven by an electrochemical potential gradient across the membrane; transport through an H+-ATP-ase ion pump; the involvement of zinc-chelate transport system; and ion channels (Yang and Römheld, 1999). A number of attributes are characteristic of zinc-efficient genotypes, such as more and finer small roots (=0.2 mm), the release of zinc chelating phytosiderophores, and the efficient use and compartmentalization of zinc within cells (Rengel, 001).

2.8. Zinc in Human Physiology and the Symptoms of Zinc Deficiency

Zinc is required for virtually all aspects of cellular metabolism (Ruz, 2003); among other functions, zinc forms the prosthetic group of numerous enzymes, as well as the receptor proteins for steroid and thyroid hormones and vitamins A and D 1999). Because zinc in excess of short-term metabolic needs is either excluded from absorptio or excreted, the human organism lives with perpetually marginal zinc nutrition (Solomons, 2003); therefore, it is obvious that insufficient zinc in the diet will quickly have adverse consequences. Zinc malnutrition has been linked to a number of symptoms, including behavioral alterations such as anorexia, depression, and psychosis; impaired growth and development; gastrointestinal problems such as diarrhea and impairment of nutrient absorption; and impaired immunity (Solomons, 2003). In juveniles, zinc deficiency can lead to slow growth or even periods of arrested growth, and to the delay of sexual maturity. Zinc deficiency can also contribute to Vitamin A deficiency, since lack of zinc can impair the synthesis of Retinol Binding Protein (Bender, 1999).

2.9. Iron in Human Physiology and the Symptoms of Iron Deficiency

The importance of iron as the central atom of hemoglobin, and the anemia caused by the lack of it, are well known (Tuman and Doisy, 1978). Iron is also a component of myoglobin (Zhang, *et al.*, 2004), which has a function in the storage of oxygen in muscle tissue, and of the cytochrome system (Tuman and Doisy, 1978), which is important in he derivation of energy from cellular respiration. Iron, with zinc and selenium, has an immunomodulating function (Lyons, *et al.*, 2004). In addition to causing anemia, lack of sufficient iron can cause impaired cognitive development and physical coordination in children less than two years of age, limitation of the ability to perform endurance physical activity, impairment of the immune system, and a number of other symptoms (Lynch, 2003). Iron deficiency has also been shown to reduce the effectiveness of iodine supplementation (Lyons, *et al.*, 2004).

2.10. Iron Deficiency in Plants

Iron deficiency in plants is a major problem worldwide because of low iron availability the aerobic environment and at biological pH, especially in the calcareous soils that cover about one-third of the surface of the earth (Yang and Römheld, 1999; Rengel, 2005). There are two major strategies by which plants can overcome iron deficiency. Strategy I plants, dicotyledons and non-graminaceous monocotyledons, iron efficiency is a function of a number of induced responses by plant roots; primarily, an increased rate of reduction reactions (Fe^{3+} to Fe^{2+}) at the root surface, an increased rate of rhizosphere acidifi ion, increased release of phenolic compounds, e.g., caffeic and chlorogenic acid, and the accumulation of citric acid in plant roots (Yang and Römheld, 1999). Three types of root membrane-bound Fe (III) reductases have been suggested for strategy I plants. There are standard reductases which occur in the plasma membranes of all higher plant species but do not reduce chelated iron compounds, and inducible and constitutive reductases, which can reduce Fe (III) in chelates from various origins. Apparently, inducible reductases takes effect upon the increased activity of constitutive reductase under iron stress conditions (Rengel, 2002). Strategy plants, which consist of the *graminaceæ*, respond to iron deficiency by the increased release of phytosiderophores (Rengel, 2002). Strategy II plants also possess membrane-bound standard reductases that are capable of reducing electron donor molecules such as ferricyanide, but they do not possess the inducible and constitutive reductases of Strategy I plants (Yang and Römheld, 1999).

2.11. Improvement of iron and zinc concentration in plants

Staple crops that are micronutrient-enriched, either through traditional breeding or molecular biological techniques, are powerful tools that can help the people who are most vulnerable to micronutrient malnutrition (Welch, 2002). Increasing the amounts of micronutrient metals stored in seeds and grains of staple food crops increases the yield potential of these crops when they are sown in the micronutrient-poor soils so prevalent in the developing world (Welch, 2002). Available research has indicated that micronutrient enrichment traits are available within the genomes of major crops; as a result, improvements in micronutrient concentration can be made without adversely affecting yield (Welch and Graham, 2002). Furthermore, enrichment traits appear to be stable across soil types and climatic env ronments (Welch and Graham, 2002). Further research is needed to determine if increasing levels of micronutrients in staple foods can significantly improve the nutritional status of people suffering deficiency (Welch and Graham, 2002). In Zambia the main sources of zinc and iron are fruits (avocado, figs, grapes, lemon, and water melon), vegetables (amaranthus leaves, beans, potatoes and pumpkin) and meat (beaf and pork products).

2.12. Current Biofortification Efforts

The process of genetically enhancing the nutritional properties of crops is called Biofortification. There are a number of programs ongoing focused on improving micronutrient densities in staple crops. A wide range of wheat germplasm is being studied at CIMMYT to determine the range of iron and zinc concentrations in whole grains as well as the effect of environmental conditions on these concentrations. Their data suggest there is enough genetic variability to substantially increase iron and zinc concentrations in wheat grain, and though there was a significant genotype by environment interaction, there was also a high correlation between iron and zinc ptake in the lines studied. This indicates that it should be possible to improve iron and zinc concentration simultaneously in wheat grain. Additional research has shown no negative linkage between grain yield and iron and zinc concentration (Gregorio, 2002). Researchers at CIMMYT have also evaluated grain concentration of iron and zinc for nearly two thousand maize core germplasm and breeding populations. Iron concentrations varied more than six-fold and zinc concentrations more than four-fold; these differences were attributed to both genetic and environmental factors (Gregorio, 2002). Researchers in Zambia have determined the critical level of zinc and the optimum rate of application in intensive agriculture farming systems, the results showed that 5 kg/ha of zinc sulphate significantly increased maize g in yield over the control treatment. The optimum rate of zinc was established as 10 kg/ha while the critical rate was established at 5 kg/ha. The critical soil test level of zinc was determined to be 2 p soil. It was recommended that in intensively managed commercial farming system here soil pH could be above neutral (7.0), 5 kg/ha of zinc sulphate is enough to increase requirements for maize. However, if soil test zinc level is below the critical level, 10 kg/ha of should be applied (Phiri, 2010).

Researchers at IRRI have been evaluating the genetic variability of iron and zinc concentration in rice grain. Roughly four-fold differences were found in concentrations of both micronutrients, which suggest there is genetic potential to increase the concentration of these micronutrients in rice grain. However, the effects of rice grain processing on iron and zinc levels in the edible product and the bioavailability of the iron and zinc in the rice grains are still being studied (Gregorio, 2002).

CHAPTER 3

3.0. MATERIALS AND METHODS

3.1 Study Locations

The experiment was conducted in three different locations of Region-III in Zambia for one planting season (2008/2009). This was mainly due to limited availability of planting material and also the research period is only one year. The experiment was planted at Mansa Research Station on 29th January 2009, Mutanda Research station on 21st January 2009, and Kamato/Solwezi on 1st February 2009. Mansa Research Station is located 11 Km east of Mansa Town. Mutanda Research Station is located 40km west of Solwezi town Kamato is located 35 km west of Solwezi Town.

Each site differs for climatic characteristics (Appendix 4). Genotypes were evaluated in a Randomized complete block design with three replicates in a plot size of $3m^2$ at spacing of 30cm within the row and 1m between rows.

The experiment consisted of 15 orange-fleshed sweetpotato varieties. The criteria used to choose the varieties was mainly based on availability of planting material and also this is in line with the partnership forged between International potato center (CIP) and the Zambian government through the VITAA (Vitamin A for Africa) initiative to disseminate and promote production of orange-fleshed sweetpotato (OFSP) varieties. Planting was rain-fed and carried out for each location when there was sufficient moisture to sustain good plant establishment. Healthy vines 20-25cm long were planted on ridges in a slanting position with two-thirds of the vine length buried in the soil. The fields were maintained free of weeds and no herbicides were applied. A basal dose of 50 Kg N, 20 Kg P_2O_5 and 50 Kg K_2O per ha was applied using compound 'D'

Additional 50 Kg N per ha was top-dressed when the plant was 5 weeks old. The tubers were harvested at 4 months after planting in each site and yield was based on the net plot.

The following data was recorded.

Data collected included agro ecological (site) description data, monitoring data and data at harvest. The parameters measured were vine weight, the disease, and weevil and mole damage. Disease, weevil damage ratings were based on a 1-5 scale, where 1 = no apparent damage/not present, 2 = very little damage/few present, 3 = moderate damage/numbers present, = considerable damage/numbers present and 5 = severe damage/ very high numbers present. The trials were harvested 4-6 months after planting, weight of marketable and unmarketable tubers / plot. Harvested roots were washed in tap water and allowed to air-dry before weighing. They were then rinsed in tap water, peeled with a knife, and rinsed in tap water again. Dry matter content (DM) was determined after weighing 200grams and oven- drying to a constant weight at 70°C. DM of storage roots was expressed as the average percentage of dry weight of fresh weight (Mwanga *et.al.*2007). Skin and flesh colour was recorded using the standard sweetpotato colour sweetpotato chart (Kapinga *et al.*, 2010).

The physiological efficiency and ability of a crop for converting total dry matter into economic yield is known as Harvest Index (Sharifi et.a 2009). The harvest index was calculated at harvest as a ration of tuber yield to the total biological yield and expressed as a percentage. Only the below-ground portion of the crop was used in the calculation.

The mathematical relation describe by Stoskopf (1981) was used:

$$HI = (EY/BY)\ 100$$

Where: HI is the harvest index in percent

EY is the root yield in t/ha

BY is the total biological yield in t/ha

3.2 Statistical Analysis

Data for 15 promising sweetpotato genotypes were processed for G x E interactions using additive Main Effect and Multiplicative Interaction (AMMI) models (Gauch, 1992), regression analysis (Finlay and Wilkinson,1963) . Parameter estimates were obtained using procedures of GenStat statistical package developed by VSN International Ltd.

Further characterization of the G X E interaction was using AMMI model (Gauch, 1992). The stable varieties identified according to the interpretation given by Zobel (1990) and Crossa et al. (1991) that ordinates for two principal compone plotted against each other, entries near the centre are average in the performance.

Mathematical Model;

Y_{ger} = µ+ a_g + $ß_e$+S_n?$_n$?$_{gn}$$d_{en}$+?$_{ge}$+$e_{ger}$

Where:

Y_{ger} = is the yield of genotype *g* in the environment *e* for replicate *r*,

µ = is the grand mean

a_g = is deviation of the genotype g from the grand mean,

$ß_e$ = is the deviation of the environment e from the grand mean,

Table 1: Sweetpotato (*Ipomoea batatas*) material used in the experimental trials

Variety	Skin Color	Flesh Color	Growth type	Origin
Carrot.C	Cream	Deep orange	Spreading	Tanzania
K135	Cream	Pink	Spreading	CIP
Zambezi	Pink	Deep orange	Erect	Zambia
Mayai	Cream	Intermediate orange	Erect	Tanzania
K566632	Intermediate pink	Deep orange	Erect	Kenya
Gweri	Purple	Orange	Spreading	CIP
Pipi	Purple	Cream	Erect	CIP
K118	Cream	Orange	Spreading	CIP
Ukerewe	Cream	Cream	Erect	CIP
199062.1	Pale purple	Intermediate orange	Erect	Mozambique
Ejumula	Cream	Deep orange	spreading	Uganda
Kakamega	Purple red	Intermediate orange	Spreading	Kenya
Naspot1	Purple red	Deep orange	Erect	Uganda
Kalungwishi	Purple	Cream	Spreading	Zambia
Jewel	Copper brown	orange	Erect	USA

*Source: International Potato center (CIP)

?$_n$ = is the singular value for interaction principal component axis (IPCA) n,

?$_{gn}$ = is the genotype eigenvector value for (IPCA) axis n root of the eigen value which is also the sum of squares divided by the number of repli ions),

d_{en} = is the environment e eigenvector value for (IPCA) axis n,

?$_{ge}$ = is the residual and e_{ger} is the error term if the experiment is replicated. The eigenvectors scaled as unit vectors are unit less,

µ, a_g and $ß_e$ are additive parameters and enter the model additively while ?$_{n,}$?$_{gn}$ and

d_{ens} are multiplicative parameters and enter the model multiplicatively.

Nowadays, multiplicative models that incorporate large number of external variables (environment and genotypic variables) into the analysis of multi-location trials are being used for study of G X E interaction and for developing methods of clustering sites or cultivars into groups with statistically negligible crossover interactions. iplicative models have an additive (linear) component (i.e. intercept, main effects of sites and/or cultivars) and a multiplicative (bilinear) component G X E interaction and thus are also named linear-bilinear models (Crossa ,1990; Cork, 1985). The Additive Main effect and Multiplicative Interaction (AMMI) model which combines regular analysis of variance for additive main effects with le component analysis for multiplicative structure within the interaction has been identified by several workers including (Dixon *et al.* 2002) as the most efficient in determining the most stable and high yielding genotypes in multi-environmental trials compared to earlier procedures (Plaisted and Peterson 1959). Therefore, it has been widely used in to study the pattern of response of genotype, environment, and genotype x environment interaction, and to identify genotypes with broad or specific adaptation to target agroecologies or environments for various traits. AMMI offers provision to generate biplots which are graphical presentation of main effect means against first Interaction Principle Component Axis (IPCA)(Dixon *et al.* 2007).

3.3 Analysis of zinc and iron

This was done at the Mt. Makulu Central Research Station and the University of Zambia, School of Agricultural sciences using absorption spectrophotometer (AAS) standard procedure (Perkin, 2004).

CHAPTER 4

4.0. RESULTS

4.1 General characteristics of the locations used

The rainy season in the year under review 2008/ 2009 was good resulting in good crop growth. At Mutanda Research station, the soil is a sandy loam pH 5.5 while the soil at Mansa research station is a sandy loam with pH near to 6.0. loam soil with pH 4.5 Nutrient status was variable at all sites and each site was considered as an individual environment (Appendix 4).

Table 2: ANACOVA table for combined mean squares for all variables measured across three sites

Source Variation ppm	DF	Weevil score	Mole score	Vine wt. (t/ha)	Total plant yld. (t/ha)	Yield (t/ha)	Mrkt.yld. (t/ha)	N.Mrk.yld. (t/ha)	HI	DM (%)	ß-Car. mg/100g FW	Vit .A ug RE/100g FW	Zinc mg/100g	Iron mg/100g
Rep.														
Covariate	1	3.7	0.1	2.4	1.7	24.0	20.9	7.8	0.039	1.8	2.8	18325	1.11	3.6
Residual	1	4.8	0.5	0.7	15.2	3.0	36.2	1.1	0.001	19.8	0.2	1558	0.34	0.4
Environ.	2	34.7*	7.5*	70.9*	143.9*	78.7*	19.9*	26.7*	0.182*	8.8ns	189.6*	1316910*	103.0*	2.9ns
Variety	14	1.9*	0.5ns	6.2*	123.9*	87.6*	37.6*	19.9*	0.022*	19.8ns	31.4*	217533*	1.3ns	8.9*
Env. X variety	28	0.8ns	0.4ns	3.7ns	23.8ns	25.5*	19.5ns	10.4*	0.033*	11.4ns	10.2*	70684*	2.0ns	6.0*
Covariate	1	1.6	0.4	0.4	31.4	3.2	57.8	17.2	0.145	4.1	2.8	19292	1.2	1.0
Residual	87	0.8	0.5	2.9	18.6	15.3	11.9	3.6	0.145	11.8	2.1	14606	1.2	2.1
CV %		46.8	54.1	54.7	29.7	31.7	42.7	29.7	13.1	12.6	53.7	53.7	25.2	27.2

*significant at P=0.05

NS Non significant

4.2. Weevils damage score

Locations and varieties were significantly different (P=0.05) for weevil score (Table 2). Means for weevil score are presented in (Table 3).

Table 3: Weevil Score of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations			Mean Across Sites [z]
	Mutanda	Kamato	Mansa	
	Weevil Score[y]			
Carrot.C	1.68a	2.66abc	3.52a	2.62
K135	1.42a	1.96bc	1.34bc	1.57
Zambezi	2.09a	4.62a	2.34abc	3.01
Mayai	1.00a	3.33abc	1.99bc	2.11
K566632	1.32a	4.01ab	2.45ab	2.59
Gweri	0.62a	3.02abc	1.68bc	1.77
Pipi	0.94a	2.36bc	1.94bc	1.75
K118	0.48a	3.76abc	1.01c	1.75
Ukerewe	0.67a	2.33bc	1.96bc	1.65
199062.1	0.75a	2.96abc	2.26abc	1.99
Ejumula	0.71a	2.98abc	2.47ab	2.05
Kakamega	1.21a	2.39abc	2.24abc.	1.95
Naspot1	0.65a	1.68c	1.61bc	1.31
Kalungwishi	1.04a	1.65c	1.68bc	1.46
Jewel	1.10a	1.65bc	2.52ab	1.76
Mean[x]	**1.04**	**2.78**	**2.07**	**1.96**
CV	**76.7**	**40.4**	**30.3**	**49.1**
Loc. LSD	**0.66**			
Var. LSD	**0.87**			
For interactions				
Var. x Loc LSD	**1.57 NS**			

[z] Means from across sites
[Y] Means from each location
[X] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plot

Means followed by the same letter in a column are not significantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

The highest weevil score was 4.6 at Kamato while the lowest was 0.48 at Mutanda. The varieties with high weevil score were Carrot.C and K56632 at 2.62 and 2.59 respectively while the varieties with the lowest weevil score were Kalungwishi and Naspot1 at 1.46 and 1.31 respectively. At Mutanda, Zambezi and carrot C had the highest weevil score at 2.09 and 1.68 respectively while K118 had the lowest score at 0.48. At Kamato site, K566632 had he highest score at 4.62 while the lowest score was Kalungwishi and Jewel at 1.65. At Mansa, the highest score was Carrot.C. Locations differed significantly; had the highest weevil score followed by Mansa and Mutanda respectively, at 2.78, 1.98 and 1.04 respectively.

4.3. Moles damage score

Locations were significantly different at p=0.05 for moles score (Table 2). Means for mole score are presented in table 4. The mole score ranged from at Mutanda to 1.56 at 1.56. Kamato was in between at 1.53.

4.4. Vine weight

Locations and varieties were significant (P=0.05) for vine weight (Table 2). Means for vine weight are presented in (Table 5). The highest vine weight was 7.64 at Mansa site while the least was 0.39 t/ha at Kamato site. The varieties with high weight were K118 and Gweri at 4.52

t/ha and 4.29 t/ha, respectively. The variety with the lowest vine weight was Ejumula with 1.94 t/ha.

Table 4: Mole score of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations			Mean Across Sites [z]
	Mutanda	Kamato	Mansa	
	Moles Score[y]			
Carrot.C	1.00a	2.67a	1.10a	1.59
K135	0.63a	1.35ab	2.15a	1.38
Zambezi	0.97a	1.02b	1.48a	1.16
Mayai	0.67a	1.67ab	2.00a	1.45
K566632	0.67a	1.66ab	1.77a	1.37
Gweri	1.02a	1.32ab	1.48a	1.27
Pipi	0.69a	2.65a	1.69a	1.69
K118	1.00a	1.29ab	1.81a	1.37
Ukerewe	0.63a	1.67ab	1.81a	1.37
199062.1	0.63a	1.69ab	1.55a	1.29
Ejumula	0.65a	1.34ab	1.12a	1.04
Kakamega	0.71a	1.64ab	2.07a	1.47
Naspot1	0.67a	1.00b	1.03a	0.90
Kalungwishi	0.98a	1.01b	1.15a	1.05
Jewel	0.63a	1.02b	1.10	0.92
Mean[x]	**0.78**	**1.53**	**1.56**	**1.29**
CV	**77.3**	**50.4**	**43.4**	**54.1**
Loc. LSD	**0.50**			
Var. LSD	**0.66**			
For interactions				
Loc. x Var. LSD	**1.19NS**			

[z] Means from across sites
[Y] Means from each location
[X] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

There was no differential response for vine weight in study as evidenced by the non significant interactions.

4.5. Total plant yield

Locations and varieties were significantly different (P=0.05) for total plant yield (Table 2). Means for total plant yield are presented in (Table 6) The highest total plant yield was 25.7 t/ha at Mutanda while the lowest was 4.83 t/ha at Kamato. The varieties with high total plant yield were Naspot1 and 199062.1 with 21.88 t/ha and 19.78 t/ha respectively.

The varieties with the lowest total plant yield was Kakamega with 7.15 t/ha. The interactions were not significant at P=0.05. At Mutanda, Kalungwishi, Naspot1 and 199062.1 and K118 had the highest total plant yield at 21.3, 21.0 and 20.2 t/ha respectively and Mansa had Naspot1, 199062.1 and Ukerewe at 19.3, 19.15 and 17.43 t/ha respectively. The varieties with the lowest total plant yield were Kakamega and Ejumula at 4.83 and 9.10 t/ha at Kamato and Kakamega and Kalungwishi at 8.34 t/ha and 8.93 t/ha at the Mansa. There was a difference in locations as observed from the location means. Mutanda had the highest total plant weight of 16.7 t/ha, while Kamato and Mansa had 13.7 t/ha and 13.2 t/ha respectively.

Variations in total plant growth could be due to the growth type of the varieties. Some of the varieties were either bushy or creeping type and this be due to inherent genetic characteristics.

4.6. Root Yield

Locations, varieties and the interactions were significant at P=0.05 for yield (Table 2).The means for yields are presented in Table 7.

Table 5: Vine weight of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations: Mutanda	Kamato	Mansa	Mean Across Sites [z]
	Vine weight (t/ha)[y]			
Carrot.C	2.35ab	0.43c	3.25a	2.01
K135	1.77b	2.67ab	6.87a	3.77
Zambezi	2.32ab	1.33bc	3.16a	2.27
Mayai	1.93b	0.45c	5.25a	2.54
K566632	2.43ab	1.24bc	2.98a	2.22
Gweri	2.28ab	3.39a	7.19a	4.29
Pipi	2.86ab	1.86abc	6.04a	3.59
K118	2.56ab	3.36a	7.64a	4.52
Ukerewe	3.04ab	2.36ab	4.89a	3.43
199062.1	3.62a	1.78abc	2.10a	2.50
Ejumula	2.79ab	0.39c	2.64a	1.94
Kakamega	1.50b	0.49c	4.19a	2.06
Naspot1	3.69a	1.91abc	6.45a	4.02
Kalungwishi	2.35ab	0.61c	3.94a	2.30
Jewel	1.72b	0.42c	6.34a	2.83
Mean[x]	**2.48**	**1.51**	**4.86**	**2.95**
CV	**30.6**	**56.9**	**56.0**	**57.4**
Loc. LSD	**1.22**			
Var. LSD	**1.61**			
For interactions				
Var. x Loc LSD	**2.90NS**			

[z] Means from across sites
[Y] Means from each location
[x] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not significantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

Table 6: Total plant yield of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations			Mean Across Sites ^{z}
	Mutanda	Kamato	Mansa	
	Total Plant yield (t/ha)^{y}			
Carrot.C	17.7a-d	12.33cde	11.06ab	13.70
K135	16.6b-e	14.4a-e	13.03ab	14.68
Zambezi	15.8cde	17.00a-d	11.08ab	14.62
Mayai	16.69b-e	10.7def	14.34ab	13.91
K566632	15.9cde	9.78ef	11.12ab	12.27
Gweri	13.5cde	14.00b-e	13.87ab	13.79
Pipi	10.8de	10.7def	12.82ab	11.44
K118	19.9abc	20.2ab	13.23ab	17.78
Ukerewe	15.6cde	10.02def	17.43ab	14.35
199062.1	19.2a-d	21.0a	19.15a	19.78
Ejumula	12.5cde	9.10ef	11.14ab	10.91
Kakamega	8.27e	4.83f	8.34b	7.15
Naspot1	24.9ab	21.3a	19.43a	21.88
Kalungwishi	25.7a	17.9abc	8.93b	17.51
Jewel	16.2cde	11.63cf	1 3.05ab	13.63
Mean^{x}	**16.6**	**13.66**	**13.20**	**14.49**
CV	**26.4**	**6.18**	**34.0**	**29.7**
Loc. LSD	**3.10**			
Var. LSD	**4.08**			
For interactions				
Var. x Loc LSD	**7.37NS**			

^{z} Means from across sites
^{Y} Means from each location
^{X} Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

The locations had different root yields ranging from 9.68 t/ha at Mutanda to 10.79 t/ha at Mansa. The highest yield was 19.37 t/ha at Kamato. While the root yield was 4.34 t/ha at Kamato site. The varieties with the highest yield were Naspot 1, 199062.1 and K118 at 16.44 t/ha, 14.96 t/ha and 13.45 t/ha respectively (Table 7). The lowest yields were obtained variety Kakamega at 7.27 t/ha. There was a differential response in yield for the varieties tested as evidenced by significant interactions. At Mutanda, Kakamega, Ejumula, Pipi and Gweri had the lowest yield at 5.97 t/ha, 6.12, and 6.32 t/ha respectively and at Kamato, it was Kakamega, K566632 and Ejumula at 4.34, 8.54 and 8.71 t/ha respectively. On the other hand, the varieties with the highest yield was Naspot1 and K118 at 16.66 and 13.06 respectively and 199062.1 and Ukerewe at 19.37 and 19.20 t/ha respectively at Mansa. There was a change in the rankings of the varieties in terms of yield; Naspot1 had the second highest yields in Mutanda, high yields in Kamato and lowest yields at the Mansa.

4.6.1. Marketable yield

For marketable yield, locations, varieties and interactions were significant at P=0.05 (Table 2). Means for marketable yield are presented in (Table 8). The locations had different marketable yield ranging from 5.23 t/ha at Mansa to 9.69 t/ha at Mutanda. The highest marketable yield was 16.67 t/ha obtained at the Mutanda, while the lowest was 2.51 t/ha obtained from the Mansa. The varieties with the highest marketable yield were Naspot 1 and K118 at 13.74 t/ha and 9.57 t/ha respectively. The variety with the lowest marketable yield was Kakamega at 5.23 t/ha.

Table 7: Yield of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties across three environments of Region III -Zambia, 2008/2009

Variety	Locations			Mean Across Sites [z]
	Mutanda	Kamato	Mansa	

	Yield (t/ha)[y]			
Carrot.C	10.78ab	11.89bcd	12.07ab	11.58
K135	9.58b	11.73bcd	7.65b	9.65
Zambezi	7.91b	15.67bcd	9.42b	11.0
Mayai	12.56ab	10.25cde	9.12b	10.64
K566632	12.12ab	8.54de	9.15b	9.94
Gweri	8.55b	10.55cde	8.19b	9.10
Pipi	6.32b	8.85de	7.06b	7.41
K118	13.06ab	16.87abc	10.42b	13.45
Ukerewe	8.79b	7.68de	14.29ab	10.25
199062.1	6.47b	19.20a	19.20a	14.96
Ejumula	6.12b	8.71de	13.00ab	9.28
Kakamega	5.97b	4.34e	11.49ab	7.27
Naspot1	16.66a	19.37a	13.29ab	16.44
Kalungwishi	8.55b	17.31ab	6.49b	10.78
Jewel	11.91ab	11.21bcd	10.97 b	11.36
Mean[x]	**9.69**	**12.14**	**10.79**	**10.87**
CV	**37.3**	**5.92**	**7.00**	**31.7**

Loc. LSD	**2.81**
Var. LSD	**3.71**
For interactions	
Var. x Loc LSD	**6.69**

[z] Means from across sites
[Y] Means from each location
[X] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

There was a differential response in marketable yield the varieties tested as evidenced by the significant interactions. At Mutanda, Naspot1, K118, and Mayai had the highest yield at 16.67 t/ha, 13.06 t/ha and 12.56 t/ha respectively, however Kamato, 199062.1, Naspot1 and K118 had the highest yield at 14.82 t/ha, 14.66 t/ha and 13.04 t/ha respectively and Ukerewe, Naspot1 and Mayai at the Mansa at 10.47 t/ha, 9.88 t/ha and 6. t/ha respectively. At the Mutanda, Kakamega and Ejumula had the lowest yields at 5.97 t/ha and 6.12 t/ha respectively while at Kamato, K56632 and Ukerewe had the lowest yields of 6.54 t/ha and 5.96 t/ha respectively. Kakamega and K118 had the lowest yields at the Mansa at 2.51 t/ha and 2.60 t/ha respectively. There was a change observed in ranking of the varieties tested. Carrot.C had highest yields at Mutanda, followed by low yields at Kamato and lowest yields at the Mansa of 0.78 t/ha, 9.15 t/ha and 4.50 t/ha respectively.

Table 8: Marketable yield of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III-Zambia, 2008/2009

Variety	Locations			Mean Across Sites ^{z}
	Mutanda	Kamato	Mansa	
	Marketable yield (t/ha)^{y}			

Carrot.C	10.78ab	9.15ab	4.50c	8.14
K135	9.58b	8.58ab	4.45c	7.54
Zambezi	7.91b	11.20ab	4.52c	7.88
Mayai	12.56ab	8.23ab	6.81abc	9.20
K566632	12.12ab	6.54b	4.85c	7.84
Gweri	8.55b	7.67ab	4.19c	6.80
Pipi	6.32b	6.89b	4.65c	5.95
K118	13.06ab	13.04ab	2.60c	9.57
Ukerewe	8.79ab	5.95b	10.47a	8.40
199062.1	6.47b	14.82	5.84bc	9.04
Ejumula	6.12b	6.80b	5.57c	6.16
Kakamega	5.97b	7.22ab	2.51c	5.23
Naspot1	16.67a	14.66a	9.88ab	13.74
Kalungwishi	8.55b	11.80ab	3.46c	7.94
Jewel	11.91ab	7.80ab	4.11	7.94
Mean^{x}	**9.69**	**9.36**	**5.23**	**8.09**
CV	**37.3**	**40.8**	**39.5**	**42.7**
Loc. LSD	**2.48**			
Var. LSD	**3.27**			
For interactions				
Var. x Loc LSD	**5.91NS**			

^{z} Means from across sites
^{Y} Means from each location
^{x} Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

4.6.2. Non marketable yield

Table 9: Non marketable yield of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III-Zambia, 2008/2009

Variety	Locations			Mean Across Sites ^{z}
	Mutanda	Kamato	Mansa	

	Non marketable yield (t/ha)[y]			
Carrot.C	4.57ab	2.71ab	3.15abc	3.48
K135	5.20ab	2.89ab	1.80abc	3.30
Zambezi	5.53ab	4.29ab	3.48a	4.43
Mayai	2.20b	1.87b	2.30abc	2.12
K566632	1.38b	2.07b	3.34ab	2.26
Gweri	2.65b	3.00ab	3.63a	3.09
Pipi	1.61b	2.12b	2.05abc	1.93
K118	4.29ab	4.37ab	3.17abc	1.93
Ukerewe	3.74b	1.78b	2.78abc	3.94
199062.1	9.09a	4.21ab	3.19abc	2.77
Ejumula	3.53b	1.82b	2.78abc	5.50
Kakamega	0.80b	3.23ab	1.48c	2.71
Naspot1	4.50ab	4.66ab	3.12abc	1.84
Kalungwishi	14.77a	5.39a	1.61bc	7.26
Jewel	2.57b	3.12ab	2.43abc	2.71
Mean[x]	**4.43**	**3.18**	**2.64**	**3.42**
CV	**58.4**	**248.3**	**1.57**	**55.6**
Loc. LSD	**1.37**			
Var. LSD	**1.80**			
For interactions				
Var. x Loc LSD	**3.25**			

[z] Means from across sites
[Y] Means from each location
[X] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots
Means followed by the same letter in a column are not significantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

Locations, varieties and interactions were significantly different at P=0.05 for non marketable yield (Table 2).

Means for non marketable yield are presented in (Table 9). The highest non marketable yield varieties were Kalungwishi and 199062.1 with 7.26 t/ha and 5.50 t/ha respectively. There was a differential response in non-marketable yield for varieties tested as evidenced by the significant interactions (Table 2). At the Mutanda, Kalungwishi, 199062.1 and Zambezi had the highest non marketable yield of 14.77 t/ha, 9.09 t/ha and 5.53 t/ha respectively. Kalungwishi, Naspot 1 and K118 had the highest non marketable yield at 5.39 t/ha, 4.66 t/ha and 4.35 t/ha respective the Kamato and Mansa; Gweri, Zambezi and K566632 had the highest non marketable yield at 3.63 t/ha, 3.48 t/ha and 3.34 t/ha respectively.

However, Kakamega, K566632, Pipi and Mayai had the lowest yield in Mutanda at 0.80 t/ha, 1.38 t/ha, 1.61 t/ha and 2.20 t/ha respectively while kerewe, Ejumula and Mayai had the lowest yield at 1.78 t/ha, 1.82 t/ha and 1.87 t/ha respective akamega, Kalungwishi and Pipi had the lowest yield at 1.48 t/ha, 1.61 t/ha and 2.05 t/ha respectively. The performance of Kalungwishi changed in magnitude from 14.77 t/ha at Mutanda, 5.39 t/ha at Kamato and 1.61 t/ha at Mansa. Similar differential responses were observed by other varieties tested as observed from the results (Table 9).

4.6.3. Yield Stability analysis

The combined analysis of variance for tuber yield was significant at P=0.01. Yield data from three locations were tested for stability using multivariate model (AMMI model).

4.6.4. Additive Main Effects and Multiplicative Interaction (AMMI) Analysis

According to Gauch *et al.* 1996, ordinates for genotype IPCA scores plotted against each other, entries near the center are average in performance and stable. ANOVA across environments detected significant variation among genotypes and for the genotype x environment for yield. The analysis of variance of AMMI (Table 10) showed that the mean sum of squares due to

Table 10: AMMI analysis of variance for tuber yield of 15 orange-fleshed sweetpotato (*Ipomoea batatas*) genotypes grown in 3 environments in Region III-Zambia, 2008/2009

Source	DF	SS	MS	F	F prob
Treatments	44	2274	51.68	3.34	0.00000**
Genotypes	14	1208	86.28	5.58	0.00000**
Environments	2	253	126.25	12.31	0.00002**
Block	6	62	10.25	0.66	0.67915*
Interactions	28	814	29.05	1.88	0.01444NS
IPCA 1	15	661	44.05	2.85	0.00122**
IPCA 2	13	153	11.75	0.76	0.69854NS
Residuals	0	0			
Error	84	1298	15.45		
Total	134	3633	27.12		

** Significant at P=0.01,
* Significant at P=0.05
NS not significant

treatments, genotype, environment and genotype x environment interaction were significant; indicating a broad range of diversity existed among genotypes. The AMMI biplots (Figure 1) for tuber yield showed eight varieties and three environments around the centre of the biplots, implying large variability in genotypes and environments. Seven varieties Jewel, Carrot.C, K135, Zambezi, K566632, Mayai and Gweri were clustered near the center of the biplots indicating an average performance and stability for such genotype and environment. This biplots showed large positive IPCA 1 scores for Mansa imply total tuber yield above the grand mean (12.35 t/ha). However, the environment at Mutanda Research site and Kamato site had negative IPCA 1 values.

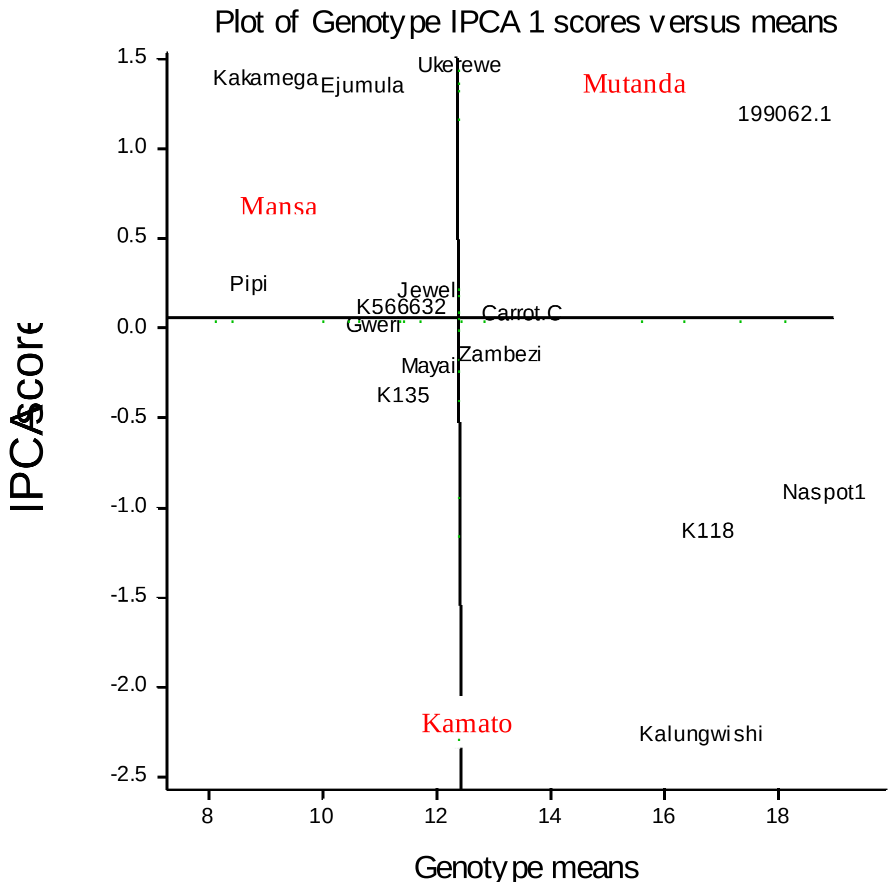

Figure1: Biplots of the first AMMI interaction (IPCA) scores (Y-axis) plotted against mean fresh tuber yield (X-axis) for 15 OFSP genotypes in 3 environments in Region III.

Varieties with large IPCA 1 scores, either positive or negative ection were highly interactive. In this study, 199062.1, Ejumula, K118, Kalungwishi, Naspot1 and Ukerewe had yields.

4.7. Harvest Index

Locations, varieties and the interactions were significantly different at P=0.05 (Table 2).

Table 11: Harvest index of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations			Mean Across Sites [z]
	Mutanda	Kamato	Mansa	
	Harvest Index[y]			
Carrot.C	0.867a	0.96a	0.68ab	0.83
K135	0.89a	0.79cd	0.48bc	0.72
Zambezi	0.84ab	0.92ab	0.70ab	0.82
Mayai	0.87a	0.96ab	0.65ab	2.48
K566632	0.83ab	0.86a-d	0.71ab	0.8
Gweri	0.83ab	0.75e	0.49bc	0.67
Pipi	0.72b	0.84a-d	0.53bc	0.7
K118	0.87a	0.83bcd	0.47bc	0.72
Ukerewe	0.80ab	0.77d	0.68ab	0.75
199062.1	0.81ab	0.91abc	0.83a	0.85
Ejumula	0.79ab	0.96ab	0.70ab	0.82
Kakamega	0.84ab	0.92ab	0.27c	0.68
Naspot1	0.85ab	0.91abc	0.67ab	0.81
Kalungwishi	0.90a	0.97a	0.57ab	0.81
Jewel	0.89a	0.96a	0.57ab	0.81
Mean[x]	**0.84**	**0.89**	**0.6**	**0.78**
CV	**8.4**	**7.2**	**21.2**	**13.1**
Loc. LSD	**0.073**			
Var. LSD	**0.096**			
For interactions				
Var. x Loc LSD	**0.174**			

[z] Means from across sites
[Y] Means from each location
[x] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan’s Multiple Range Test.

The location means ranged from60% at Mansa to 89% at Kamato. The varieties with high harvest index were 199062.1, Carrot.C and Mayai at 85%, 83% and 83% respectively. Gweri, Kakamega and Pipi had the lowest HI with values of 67%, 8% and 70% respectively.

Significant interactions (P=0.05) between HI and varieties were detected for HI, differential variety response to HI (Table 2). Table 11 presents the means for the interactions. The variety with the highest HI was 199062.1 with 85% le the lowest was 67% for Gweri. In terms of ranking, there is a change in magnitude as observed in all the varieties tested. For example, Gweri had a harvest index of 83% at Mutanda, 75% at Kamato and 49% at Mansa (Table 11).

4.8. Dry matter content

Locations, varieties and interactions were not signifi different at P=0.05 (Table 2).Means for dry matter content are presented in Table 12.

4.9. Beta carotene

For beta carotene, locations, varieties and their interactions were significantly different at P=0.05 (Table 2). Zambezi had the highest beta carotene content of 8.34mg/100g while Kalungwishi had the lowest at -0.01mg/100g at Mutanda while K566632 and Pipi had the and lowest beta carotene at 9.23 mg/100g and -0.01mg/100g respectively.

Table 12: Dry matter of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations	Mean Across

				Sites [z]
	Mutanda	Kamato	Mansa	
	Dry matter (%)[y]			
Carrot.C	28.28a	26.73abc	34.18a	29.73
K135	28.00a	27.09abc	24.25b	26.45
Zambezi	24.03a	22.25c	23.24b	23.17
Mayai	23.11a	27.31abc	27.21ab	25.88
K566632	25.57a	28.22abc	26.62ab	26.80
Gweri	27.40a	27.31abc	24.53b	26.41
Pipi	28.39a	26.88abc	28.30ab	27.86
K118	29.00a	32.84a	26.16b	29.33
Ukerewe	28.71a	24.48bc	23.70b	25.63
199062.1	27.96a	29.55ab	30.25ab	29.25
Ejumula	24.59a	32.25a	30.35ab	29.06
Kakamega	24.38a	28.22abc	26.51b	26.37
Naspot1	28.07a	25.92abc	26.48ab	26.82
Kalungwishi	29.39a	27.91abc	23.56b	28.74
Jewel	26.37a	29.51ab	29.32ab	28.40
Mean[x]	**26.88**	**27.78**	**26.98**	**27.21**
CV	**11.5**	**12.4**	**13.2**	**12.6**
Loc. LSD	**2.47**			
Var. LSD	**3.26**			
For interactions				
Var. x Loc LSD	**5.88NS**			

[z] Means from across sites
[Y] Means from each location
[X] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

Table 13: Beta carotene of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Clone	Locations	Mean Across Sites [z]

	Mutanda	Kamato	Mansa	
	Beta Carotene^{y}			
Carrot.C	4.12bcd		5.94bc	5.03
K135	3.51b-e		4.81c	4.16
Zambezi	8.34a		7.30abc	7.82
Mayai	4.92abc		8.12ab	6.52
K566632	6.52ab		9.23a	7.88
Gweri	4.68abc		4.72c	4.70
Pipi	0.31de		-0.01d	015
K118	5.03abc		4.82c	4.93
Ukerewe	1.15cde		0.51d	0.83
199062.1	6.51ab		5.85bc	6.18
Ejumula	5.25abc		7.20abc	6.23
Kakamega	3.06b-e		5.52bc	4.29
Naspot1	0.17de		0.07d	0.12
Kalungwishi	-0.01e		-0.07d	-0.04
Jewel	3.83b-e		0.19d	2.01
Mean^{x}	**3.82**		**4.28**	**4.05**
CV	**54.2**		**35.8**	**53.7**
Loc. LSD	**1.04**			
Var. LSD	**1.38**			
For interactions				
Var. x Loc LSD	**2.48**			

^{z} Means from across sites
^{Y} Means from each location
^{X} Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots
There is no data for Kamato site

Means followed by the same letter in a column are not significantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

Table 14: Vitamin A content of orange-fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III-Zambia, 2008/2009

Variety	Locations	Mean Across

	Mutanda	Kamato	Mansa	Sites[z]
	Vitamin A content[y]			
Carrot.C	342.2bcd		495.1bc	418.65
K135	292.7b-e		400.8c	346.8
Zambezi	694.9a		608.0abc	651.5
Mayai	410.2abc		677.0ab	543.6
K566632	543.2ab		769.1a	656.2
Gweri	389.7abc		393.3c	391.5
Pipi	25.7de		2.2d	13.95
K118	419.1abc		401.9c	410.5
Ukerewe	95.5cde		42.6d	69.05
199062.1	542.7ab		487.3bc	515
Ejumula	437.2abc		599.7abc	518.5
Kakamega	255.1b-e		459.6bc	357.4
Naspot1	14.3de		5.5d	9.9
Kalungwishi	-0.9e		-5.9d	3.4
Jewel	319.4b-e		15.9d	167.7
Mean[x]	**319**		**357**	**338**
CV	**54.2**		**35.8**	**53.7**
Loc. LSD	**86.9**			
Var. LSD	**114.6**			
For interactions				
Var. x Loc LSD	**206.8**			

[z] Means from across sites
[Y] Means from each location
[x] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots
There is no data for Kamato site

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

The location means ranged from 3.82 mg/100g at Mutanda to 4.28 mg/100g at Mansa.The highest beta carotene was 9.23mg/100g from Mansa while the lowest was -0.01mg/100g from both Mutanda and Mansa. K566632 had the highest beta carotene while Kalungwishi had the lowest beta carotene. The performance of Carrot.C changed in magnitude from 4.12 mg/100g at Mutanda to 5.94mg/100g at Mansa. Similar differential responses were observed in other varieties tested in the study (Table 13).

4.10. Vitamin A

Locations, varieties and their interactions were significant different at P=0.05 (Table 2).

Means for iron concentration are presented in table 14.

At the Mutanda, Zambezi, K566632, 199062.1 and Ejumula had the highest vitamin A content at 694.9 mg/100g, 543.2 mg/100g, 542.7 mg/100g and 437.2 mg/100g respectively. The lowest Vitamin A was observed from Kalungwishi, Naspot1 and Pipi at -0.9 mg/100g, 14.3 mg/100g and 25.7mg/100g respectively. At Mansa, K566632 and Mayai had 769.1 mg/100g and 677.0 mg/100g respectively while Kalungwishi, Pipi and Jewel had lowest vitamin A at -0.9 mg/100g, 14.3 and 25.7mg/100g respectively. In terms of rankings, there was a change in magnitude from 342.2 mg/100g to 495.1mg/100g as observed from Carrot.C at the Mutanda and Mansa, respectively. The location means differed from 319 mg/100g at Mutanda to 357 mg/100g at Mansa. High vitamin A content was observed in K566632 Kalungwishi and the lowest content of vitamin A was observed in Kalungwishi.

4.11. Zinc Concentration of Sweetpotato roots

Table 15: Zinc concentration of orange- fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations	Mean Across

	Mutanda	Kamato	Mansa	Sites [z]
	Zinc Concentration (mg/100g)[y]			
Carrot.C	4.28bc	2.10a	5.52a	3.97
K135	5.48abc	2.11a	6.33a	4.64
Zambezi	5.79a	1.48a	5.63a	4.30
Mayai	4.21c	2.26a	5.58a	4.02
K566632	5.84a	2.09a	6.21a	4.71
Gweri	5.85a	3.02a	4.33a	4.40
Pipi	4.88abc	2.45a	3.89a	3.74
K118	6.02a	3.01a	5.90a	4.98
Ukerewe	4.80abc	1.85a	4.61a	3.75
199062.1	5.54abc	2.39a	4.33a	4.09
Ejumula	5.95a	2.02a	5.46a	4.48
Kakamega	4.70abc	1.97a	5.98a	4.22
Naspot1	5.60ab	2.96a	4.25a	4.27
Kalungwishi	5.66a	2.05a	7.17a	4.96
Jewel	4.90abc	1.74a	6.42a	4.35
Mean[x]	**5.30**	**2.23**	**5.44**	**4.32**
CV	**12.8**	**41.0**	**27.0**	**25.2**
Loc. LSD	**0.753**			
Var. LSD	**1.03**			
For interactions				
Var. x Loc LSD	**1.85NS**			

[z] Means from across sites
[Y] Means from each location
[X] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not ficantly different at P=0.05 level of significance, according to Duncan’s Multiple Range Test.

4.12.Iron concentration of sweetpotato roots

Table 16: Iron concentration of orange- fleshed sweetpotato (*Ipomoea batatas*) varieties grown in 3 locations of Region III -Zambia, 2008/2009

Variety	Locations	Mean Across

	Mutanda	Kamato	Mansa	Sites [z]
	Iron Concentration (mg/100g)[y]			
Carrot.C	3.60b	6.51ab	4.51a	4.87
K135	5.42ab	6.03ab	4.76a	5.40
Zambezi	5.19ab	4.84bc	5.62a	5.22
Mayai	5.47ab	5.74abc	5.89a	5.70
K566632	2.98b	5.65abc	6.70a	5.11
Gweri	3.74b	3.70bc	6.37a	4.60
Pipi	3.16b	3.74bc	5.98a	6.44
K118	3.74b	2.75c	6.86a	6.68
Ukerewe	8.06a	6.52ab	6.334a	6.97
199062.1	3.73b	4.64bc	5.78a	4.72
Ejumula	5.61ab	4.52bc	4.39a	4.84
Kakamega	5.91ab	4.91bc	4.93a	5.25
Naspot1	11.20a	8.14a	4.82a	8.05
Kalungwishi	5.18ab	6.44ab	5.18a	5.60
Jewel	4.13b	4.45bc	4.66a	4.41
Mean[x]	**5.14**	**5.24**	**5.52**	**5.30**
CV	**31.1**	**30.7**	**21.0**	**27.2**
Loc. LSD	**1.04**			
Var. LSD	**1.37**			
For interactions				
Var. x Loc LSD	**2.47**			

[z] Means from across sites
[Y] Means from each location
[X] Overall means for all varieties per site
Each data was from three replications of 1.0m x 3m net plots

Means followed by the same letter in a column are not signif different at P=0.05 level of significance, according to Duncan's Multiple Range Test.

Locations were significantly different for zinc concentration at P=0.05 (Table 2). The varieties and interactions were not significantly different while locations were significantly different at P=0.05. Location means ranged from 2.23 mg/100g at Kamato to 5.44 mg/100g at Mansa. Means for zinc contents of sweetpotato from different variet given in Table 15.

For iron concentration, varieties and interactions were significantly different at P=0.05 (table 2).

At the Mutanda, Naspot1 and Ukerewe had the highest Iron concentration at 11.20 mg/100g and 8.06 mg/100g. The lowest iron concentration was from K566632 and Pipi at 2.9 mg/100g and 3.16 mg/100g, respectively. At Kamato, 199062.1 and Ukerewe had the highest iron concentration at 8.14 ppm and 6.52 ppm respectively. At Mansa, K118 and K566632 had 6.86 mg/100g and 6.70 mg/100g, respectively while Carrot.C Ejumula had the lowest iron concentration of 4.51 mg/100g and 4.39 mg/100g respect ly. Across locations, Naspot1 had the highest iron concentration followed by Ukerewe with 8.05 mg/10 and 6.97 mg/100g, respectively while Jewel had the lowest Iron concentration at 4.41 mg/100g. In terms of ranking, there was a change in magnitude in the iron concentration. Carrot.C had 3.60 mg/100g at Mutanda followed by 6.51 mg/100g at Kamato and 4.41 mg/100g at the Mansa.

CHAPTER 5

5.0. DISCUSSION

5.1. Performance of Clones

The study revealed that locations, varieties and their interactions were significantly different (P=0.05) for yield.

The highest yields were identified in varieties Naspot1, 199062.1 and K118 with 16.44 t/ha, 14.96 t/ha and 13.45 t/ha respectively. The varieties Kakamega and Pip had lower yields at 7.27 t/ha and 7.41 t/ha respectively. Simwambana *et al.* (2003) reported a potential yield of sweetpotato in Zambia ranging from 15 t/ha to 35 t/ha, which was in the same range as those reported by Kapinga *et.al.* (2005). In terms of yield, the results point to the gap between sweetpotato yield from research station experiments an yields from farmers' fields in Zambia, which averages from 2-4 t/ha (FoDiS Information series, 2009).

The varieties used in this study showed lower yields ranging from 7.27 t/ha to 16.44 t/ha and low dry matter content ranging from 23.17 t/ha to 29.73 t/ha. The reduction observed in the total and marketable root yields of sweetpotato varieties in this study could be due to weevil damage and mole attack. These results confirmed the findings of Lowe and Wilson (1975), who found that weevils and moles cause significant damage and losses to storage root yield in Sweetpotatoes

5.2. Pests and Diseases

It was also revealed in this study that locations were significantly different at p=0.05 for moles attack. In this study, however, the current study showed that damage due to weevil and pests was not deterred by the low dry matter. The nutritive content of orange-fleshed Sweetpotatoes could be the factor most important in attracting moles and weevils Kapinga *et.al.* (2005). in which orange- fleshed Sweetpotatoes are said to be attractive in colour, sweeter and less fibrous. Mole attack was different at different locations. Yield losses from weevil attack on sweetpotato are normally from 15 to 30 percent, but may be as high as to 97 percent if pest populations go unchecked (Gregorio, 2002).

The varietal differences observed in this study could have been due to varietal response to weevil and pest damage.

When the weevil and mole damage was compared to the root yield, variety Naspot1 showed resistant to mole attack (score=0.9) and weevil damage (score=1.31) resulting in the root yield of 16.44 t/ha. It was observed that variety Jewel which was attacked by moles (0.92) and weevils (score 1.76) resulting in root yield of 10.78 t/ha. However, variety Carrot.C was seriously attacked by weevils (Score=2.62) and moles (score=1.59) but had a high yield of 11.58 t/ha. This could have been due to some genetic characteristics of the variety such as having roots per plant than other varieties.

The varieties which had high yields had high harvest index. The results from the current study are similar to Naspot1, 199062.1, and K118 which had high harvest index, while the low yielding varieties like Kakamega and Pipi had low harvest index. Similar results have been reported by Alam *et.al.* (2009) in rice, who found that harvest index was higher indicating efficient translocation of assimilates for grain production of economic yield.

The observed differences among the genotypes for HI reflect the inherent difference among the varieties in their partitioning of assimilates. However, it was reported that increasing plant density above a critical plant density resulted in a decrease in HI (Mobasser *et al.* 2007).

5.3. Agronomic Attributes

There were observed differences for plant attributes among locations and among genotypes. These differences can be attributed to the growth habit as creeping types which gave an average vine weight of 3.57 t/ha compared to 2.54 t/ha for the erect ones. Similarly, the creeping types gave an average of total plant weight of 17.57 t/ha and 12.44 t/ha for the erect ones.

The current study findings are supported by other research findings which indicate that erect type varieties had significantly higher growth than bushy (erect) type and this could be attributed t its inherent genetic characteristic (Alcoy,2007). In this study 6 of the varieties used were creeping type while the other 7 varieties were erect type.

5.4. Nutritive Parameters

The study revealed that locations, varieties and interactions for ß-carotene and Vitamin A concentrations of sweetpotato were significantly different.

Carotenoids represent the most widespread group of naturally occurring pigments in nature. They are primarily of plant origin and ß-carotene, with few exceptions, predominates. ß-carotene serves as an important nutritional component in foods, as a major precursor of vitamin A, and provides pleasant yellow-orange colors to food (Simon, 1997).The concentration of ß-carotene in sweetpotato were low (0.01 mg/100g FW) in some varieti such as Kalungwishi and Pipi and relatively high 8.34 to 9.23 mg/100g FW in varieties such as Zambezi and K566632 (Table 15). The levels of ß-carotene content obtained in this study are similar to those reported by other researchers (Ndirigwe et al., 2005, Manrique and Hermann, 2001, Takahat 1995) who found ß-carotene to range from 0.00 ug/100g to 116.9 ug/g.

The varietal differences observed above reflect the wide spectrum of the root flesh color of sweetpotato. Woofel (1992) and Low *et al.* (1997) suggested that cultivars having more than 100 ug/100g (1.0mg/100g) retinol were good sources of vitamin A. The picture with regards to Vitamin A is similar to that of beta-carotene on the basis that the predominant Carotenoids in sweetpotato roots is beta-carotene which represents the main source of provitamin A in the roots (Takahata, 1995; Takahata *et al.*, 1993). In the current study the beta carotene and Vitamin A were highly correlated (r=0.99).

Results from the current study showed that Zinc concentration of orange-fleshed Sweetpotatoes was significantly different (P=0.05) due to the locations. Appendix 4 shows that the zinc contents of soils from Mutanda, Kamato and Mansa were considerably higher than the critical value of 0.8 ppm indicated by Lindsay and Norwell (1969). It also shows that zinc levels in sweetpotato are not dependent on the genotype. The results obtained in this study are similar to the findings reported by Courtney, (1996) who reported a range of 1.58 ppm to 3.67 ppm.

The significant differences observed among the locations for zinc concentration in the current study simply point to the variation of the soils with regards to the mineral content.

Courtney (1996), found clear trends of Zinc in fresh sweetpotato to vary significantly among genotypes, which is contrary to the current study results where no differences among varieties were detected. The failure to detect differences among entries in the current study can be linked to the use of limited sample of sweetpotato genotypes d few locations within a single season. Dixon and Nukenine (2000) Dixon and Nukenine (2000) cautioned that the use of fewer replications, locations and years will result in inaccurate selection for yield trials and will lead to non-detection of differences among genotypes for micronutrients.

The study revealed that iron concentration of sweetpotato roots were significantly different (P=0.05). Courtney (1996), found clear trends of Fe in fresh sweetpotato to vary significantly among genotypes, which is similar to the current study results where significant differences among varieties were detected.

Soil and variety samples were collected from three locations and analysed for zinc and iron content. The results showed variations in the concentration of both elements in the varieties, with varieties exhibiting higher Zinc concentration than the soils. The iron content of sweetpotato ranged from 2.9 mg/100g to 11.20 mg/100g. Appendix 4 shows that the iron contents of soils from Mutanda and Kamato were considerably higher than critical value of 4.5 mg/100g indicated by Lindsay and Norwell (1969) whereas the iron contents of soil from Mansa was considerably lower than the critical value. The current study shows similar results from (Reddy *et al.* 2005**)** who found concentration of Fe in the ash of needles and twigs, with each exhibiting lower concentration than the soils.

Zinc enters the plant mainly via root absorption of Zn^{2+} from the soil solution. Because of the low zinc concentration in the soil solution, supply of zinc by mass flow is limited and diffusion is the major process by which zinc reaches the roots (Yang and Römheld, 1999)

For dry matter, genotype and interactions were not a si icant source of variation. The dry matter levels obtained in the current study were similar to those reported elsewhere (Courtney, 1996; Masumba, 2006) who reported a range of 21.33- 42.2 %. Kapinga *et.al.* (2005), on the other hand, found dry matter of orange fleshed sweetpotato to vary among varieties contrary to the current study results and the levels were in the range 34.9% - 36.5%. The failure to detect difference among entries for DM in the current study could be due to the homogeneity, with respect to of the genotypes tested.

5.5. Stability of the sweetpotato clones

The analysis of variance of AMMI showed that the mean m of squares due to treatments, genotypes, genotypes, locations and interactions were significant, implying that there was ide variability among genotypes. The significance exhibited by interactions indicated that each of the genotype interacted differentially in various locations tested.

In this study, Gweri Carrot.C, K135, K566632, Mayai, Pipi, and Zambezi had average yield and were stable across locations , while 199062.1, Ejumula, K118, Kakamega, Kalungwishi, Naspot1 and Ukerewe were high yielding but not stable locations. The findings in this study are similar to those found in other research (Amandan *et.al.*2009).

CHAPTER 6

6.0. CONCLUSION

The present study showed substantial variability for agronomic traits and micronutrients studied among the 15 sweetpotato genotypes. Naspot 1 and 1999602.1 were the best for yields as well as for iron. Zinc content among the tested varieties were at levels that did not permit for discrimination among them suggesting the need for use of large samples of materials over a number of seasons and preferably over a number of locations.

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APPENDICES

Appendix 1: ANACOVA Table for mean squares for variables measured at Mutanda Research Station.

Source Variation	DF	Weevil score	Mole score	Vine wt. (t/ha)	Total plant yld (t/ha)	Yield (t/ha)	Mrkt.yld. (t/ha)	N.Mrk.yld. (t/ha)	HI	DM (%)	ß-Car. mg/100g FW	Vit .A ug RE/100g FW	Zinc ppm	Iron ppm
Rep.														
Covariate	1	10.9	2.7	3.7	49.0	25.8	106.7	27.5	0.01	2.8	3.1	21263	1.5	1.7
Residual	1	0.1	0.2	1.7	43.8	28.2	36.1	0.5	0.001	15.4	2.2	15534	0.1	0.2
Variety	14	0.5ns	0.1ns	1.2*	63.5*	54.5*	28.7*	34.9*	0.006ns	12.4ns	18.7*	129808*	1.1*	13.7*
Covariate	1	0.4	0.1	0.7	29.7	39.3	0.02	37.3	0.01	6.9	3.6	24873	0.1	0.1
Residual	27	0.6	0.4	0.6	19.3	19.6	13.1	6.7	0.01	9.5	4.3	29804	0.5	2.6
CV %		76.7	77.3	30.6	26.4	31.3	37.3	58.4	8.4	11.5	54.2	54.2	12.8	31.1

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*significant at P=0.05

NS not significant

Appendix 2: ANACOVA Table for mean squares for variables measured at Mansa Research Station.

Source Variation	DF	Weevil score	Mole score	Vine wt. (t/ha)	Total plant yld. (t/ha)	Yield (t/ha)	Mrkt.yld. (t/ha)	N.Mrk.yld. (t/ha)	HI	DM (%)	ß-Car. mg/100g FW	Vit .A ug RE/100g FW	Zinc ppm	Iron ppm
Rep.														
Covariate	1	0.16	0.68	5.4	21.1	0.86	5.3	2.0	0.08	27.2	0.36	2435	2.0	0.20
Residual	1	6.4	0.03	1.1	26.0	0.68	87.4	1.0	0.10	5.7	0.06	313	0.98	0.10
Variety	14	0.7ns	0.42ns	8.8ns	32.1ns	28.0ns	15.5ns	1.5*	0.06*	14.0ns	31.8*	220913*	2.7ns	1,39ns
Covariate	1	1.5	0.31	0.1	48.9	2.5	24.5	4.0	0.05	49.4	0.18	1238	3.17	0.26
Residual	27	0.4	0.46	7.4	20.2	13.8	4.3	0.7	0.02	12.6	2.34	16277	2.16	1.35
CV %		30.3	43.4	56.0	34.0	34.5	39.5	31.6	21.2	13.2	35.8	35.8	27.0	21.0

*significant at P=0.05

NS not significant

Appendix 3: ANACOVA Table for mean squares for variables measured at Kamato.

Source Variation	DF	Weevil score	Mole score	Vine wt. (t/ha)	Total plant yld. (t/ha)	Yield (t/ha)	Mrkt.yld. (t/ha)	N.Mrk.yld. (t/ha)	HI	DM (%)	ß-Car. mg/100g FW	Vit .A ug RE/100g FW	Zinc ppm	Iron ppm
Rep.														
Covariate	1	1.18	1.11	4.7	0.86	1.5	2.52	2.76	0.0203	17.4	0	0	2.97	2.93
Residual	1	0.73	0.09	0.6	2.98	4.5	14.6	1.22	0.0003	0.7			0.23	4.77
Variety	14	2.27ns	0.87ns	3.2*	71.44*	60.3*	26.7ns	4.01ns	0.0159*	20.8ns	0	0	0.54ns	75.86*
Covariate	1	0.09	0.2	0.60	25.94	34.7	11.0	0.93	0.0093	10.0	0	0	0.79	0.006
Residual	27	1.26	0.60	0.7	12.92	11.8	14.6	2.35	0.0041	11.9	0	0	0.84	69.99
CV %		40.4	50.4	56.9	26.3	28.3	40.3	488.3	7.2	12.4	0	0	40.0	30.7

*significant at P=0.05

Ns not significant

Appendix 4: Geographic and soil physic-chemical characteristics of the different sites used in the study.

District	Location	Rainfall [y]	Altitude [y]	Soil texture	pH	N	Fe (ppm) [x]	Zn (ppm) [x]	Cu (ppm) [x]
Solwezi	Mutanda	950 mm	1400 m	Sandy loam	5.5	0.145	90	<1	4
Solwezi	Kamato	950 mm	1400 m	Sandy clay loam	4.5	0.145	331	1	8
Mansa	Mansa	-	1400 m	Sandy loam	6.0	5.7	0.870	4.73	0.78
Key for interpretation									
High					5.5-6.5	>0.30	4.5	0.8	>2.0
Low					<4.5-5.0	0.10	<4.5	2.0	2.0

[x] Mt. Makulu Central Research Station and School of Agricultural science lab (UNZA)

[y] Metrological Department of Zambia

Appendix 5: Table of Correlation Coefficients for all variables measured of 15 orange-fleshed sweetpotato varieties grown in 3 locations of Region-III of Zambia 2008/2009 growing season

Parameters	Standcount	Yield	D.M	Vine wt.	T.plant yld	HI	W.D	MA	Zinc	Iron	? -Carote	Vit.A
Standcount	1											
Yield	0.172	1										
D.M	0.102	0.0964	1									
Vine wt.	-0.418	-0.110	0.003	1								
T.plant yld.	0.236	0.835*	0.072	0.206	1							
HI	0.632*	0.342	0.060	-0.768	0.287	1						
W.D	-0.053	-0.183	0.022	-0.123	-0.195	0.0880	1					
MA	-0.199	-0.192	-0.055	0.142	-0.195	-0.237	0.369	1				
Zinc	-0.438	0.057	-0.148	0.281	0.006	-0.391	-0.402	-0.182	1			
Iron	-0.009	0.088	-0.039	0.081	0.105	-0.022	-0.072	0.087	-0.050	1		
? -Carote	-0.286	0.004	-0.079	0.175	-0.028	-0.247	-0.210	-0.050	0.523*	-0.089	1	
Vit.A	-0.287	0.004	-0.079	0.176	-0.027	-0.247	-0.211	-0.050	0.523*	-0.088	1.00*	1

Key

Yield	Tuber yield	Zinc	Zinc content
D.M	Dry matter	MA	Mole attack
Vine wt.	Vine weight	W.D	Weevil damage

T.plant yld.	Total plant yield	HI	Harvest index
Iron	Iron content		
? -Carote	Beta carotene		
Vit.A	Vitamin A		