EVALUATION OF AFRICAN EGGPLANT ACCESSIONS FOR PHENOTYPIC TRAITS AND ADAPTATION TO WATER STRESS

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DECLARATION

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

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DEDICATION

I dedicate this work to my loving parents Mr. Moses Koech and Mrs. Selly Koech for their continued support in my academic work and guidance in life.

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LIST OF ABBREVIATIONS AND ACRONYMS

ALVs	African leafy vegetables
ANOVA	Analysis of variance
CEC	Cation exchange capacity
DARwin	Dissimilarity analysis representation for windows
DNA	Deoxyribonucleic acid
FAO	Food and Agriculture Organization of the United Nations
GBK	Genebank of Kenya
GD	Genetic distance
GDP	Gross domestic product
GS	Genetic similarity
HCDA	Horticultural Crops Development Authority
ITC	International Trade Centre
IBPGR	International Board for Plant Genetic Resources
KALRO	Kenya Agricultural and Livestock Research Organization
LSD	Least significant difference
MOA	Ministry of Agriculture
MT	Metric tonnes
SPAD	Soil Plant Analysis Development
UPGMA	Unweighted pair-group method using arithmetic averages
USD	United States of America dollar

GENERAL ABSTRACT

African eggplant is one of the indigenous vegetables with a great potential for improving food security and income generation among rural and urban resource-poor communities. However, its productivity is low partly due to lack of suitable varieties and drought stress. Systematic characterization of the existing African eggplant accessions is therefore required to identify key agronomic and quality traits for its improvement. Existing germplasm of the eggplants have not been evaluated for agronomic potential under water stress and non-water stressed environments. In addition, the nutritional quality of existing accessions and germplasm has not been determined. The objectives of this study were: 1. to evaluate African eggplant accessions for morphological and agronomic traits; and 2. to determine the effect of water stress on growth, yield and nutritional quality of selected African eggplant accessions. Field and greenhouse experiments were conducted in 2014 and 2015 at the University of Nairobi's Kabete Field Station. In the first objective, 72 African eggplant accessions from four species namely *Solanum aethiopicum* (50 accessions), *Solanum macrocarpon* (1 accession), *Solanum anguivi* (6 accessions) and *Solanum* species (15 accessions) were characterized in both the greenhouse and field based on the available African eggplant descriptors list. Data were collected on nine quantitative traits (plant height, leaf length, leaf width, fruit length, fruit breadth, fruit weight, number of fruits per plant, chlorophyll content and days to 50% flowering) and eight qualitative traits (growth habit, leaf prickles, leaf hairs, fruit breadth, fruit length, flower colour, fruit shape and fruit position) measured at flowering and fruit maturity stages. In the second objective, a study was conducted in a greenhouse at the University of Nairobi's Kabete Field Station to determine the genotypic variation in yield and nutritional quality of 20 selected African eggplant accessions grown under water stress (40%, 60% and 80% field capacity) and non-water stress (100% field capacity) conditions. The experiments were laid

out in a randomized complete block design with three replications. Data was collected on growth components (plant height, stem girth, single leaf area and fruit weight), physiological parameters (stomatal conductance, canopy temperature, leaf relative water content and chlorophyll content) and chemical components (β-carotene, vitamin C, total soluble solids, titratable acidity, pH, Mg, Ca, Fe and Zn measured at vegetative, flowering and fruit maturity stages. The analysis of variance indicated significant differences ($P<0.05$) for most of the accessions grown in the field and greenhouse. Fruit length was significantly ($P<0.05$) and positively correlated with fruit breadth ($r = 0.59$ and 0.60), fruit weight ($r = 0.72$ and 0.73) and leaf blade width ($r = 0.34$ and 0.28 for field and greenhouse grown accessions, respectively). However, fruit length correlated negatively but highly significantly with the number of fruits per plant ($r = -0.32$ and -0.31 for field and greenhouse grown accessions, respectively). On the other hand fruit length was positively correlated with leaf blade length ($r = 0.09$ and 0.09) and plant height ($r = 0.15$ and 0.16) while days to flowering had a positive correlation with SPAD value ($r = 0.08$ and 0.06), respectively, for field and greenhouse grown accessions. Cluster analysis placed the accessions into two cluster groups with cluster I having 51 accessions and cluster II having 21 accessions. Both in the field and greenhouse, 87.5% of the accessions showed an upright growth, intermediate growth habit (9.7%) and prostrate growth habit (2.8%). Accessions with leaf prickles and leaf hairs were 68.1% and 70.8% respectively. Shannon-Weaver diversity index (H') estimates for the qualitative characters in the field and greenhouse were high ($H'>0.750$). Principal component analysis showed that fruit parameters (fruit breadth and fruit position), flower parameter (flower colour) and leaf parameters (leaf hairs and leaf prickles) were important traits which distinctively separated the eggplant accessions. Results showed high yields in accessions RV100200, GBK050572, RV100456, RV100256 and RV100239 while the lowest yield was seen in accession RV100335. Water stress

significantly decreased fruit yield (16.6%), fruit weight (13.8%), stem girth (31.9%), plant height (20.1%), single leaf area (17.9%), stomatal conductance (57.7%), leaf relative water content (37.2%), contents of chlorophyll (12.6%), pH (6%), magnesium (43.5%), calcium (43.9%), iron (47.3%) and zinc (18.9%). However, it increased β-carotene concentration (29.5%), vitamin C (6.03%), titratable acidity (16.7%), total soluble solids (14.9%) and canopy temperature (19.7%). African eggplant accessions varied in morphological growth, fruit yield and nutritional quality. Six key traits identified for characterizing eggplant accessions were leaf hairs, leaf prickles, fruit shape, fruit breadth and flower colour. Water stress decreased growth, fruit yield, macronutrients (Ca and Mg) and micronutrients (Fe and Zn) but increased β-carotene, vitamin C and total soluble solids.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Vegetables are important components of all human diets and traditional vegetable species are especially important due to their nutritional and medicinal value (Shei, 2008). Traditional leafy vegetables are local vegetables whose leaves, young shoots, flowers and fruits are consumed (Maundu *et al*., 1999; Orech *et al.,* 2007). Most people in sub-Saharan Africa are faced with hunger and malnutrition hence leading to increased consumption of African leafy vegetables (Obel-Lawson, 2005). However, more emphasis has been accorded to exotic vegetables than local ones due to non-appreciation of African traditional vegetables, inadequate scientific information on local African vegetable species and urbanization (Shei, 2008; Obel-Lawson, 2005; Andrews, 2014).

The Solanaceae are considered among the most important plant taxa economically and comprise the most valuable vegetable crops globally. Africa is home to hundreds of Solanaceae species that have been used for food for years. African eggplant is among the many indigenous vegetables that play an important role in both subsistence production and income generation in rural and urban resource-poor communities in Africa (Chadha, 2006). African eggplant fruits have high levels of vitamin C, fibre content, calcium, iron, carbohydrates and β-carotene compared to most vegetables fruit like tomato (Hornal *et al.*, 2007). Among the important horticultural crops in Africa is African eggplant, but its yields in small holder production systems are far below the crop's potential. This is attributed to a number of yield reducing factors which include both biotic (examples birds,

insects, weeds, fungi) and abiotic (examples soil, climatic factors, topography) factors (Wicker *et al.,* 2007).

In 2010, China accounted for 58.55% of total world production of eggplant while the other major eggplant producers were India, Egypt, Iran and Turkey. The total eggplant production by these countries was 24,501,936 tons (PROTA, 2010). Eggplant is used as a vegetable as well as a traditional medicine for treatment of many diseases (Kashyap *et al.,* 2003). Annual African eggplant fruit production in Africa is estimated at 8,000 tons/ha in Senegal, 60,000 tons/ha in Cote d'ivore and 4,500 tons/ha in Burkina Faso, with small scale growers accounting for 80% of the total production (PROTA, 2010). This crop is found throughout tropical non-arid parts of Africa (PROTA, 2010). It is considered as a minor crop in most African countries and has received little research on agronomic requirements (Schippers, 2002).

The domesticated African eggplant (*Solanum aethiopicum*) has important breeding traits that remain to be exploited. The African eggplant shows a higher drought and heat tolerance than conventional eggplants. There is enormous untapped genetic diversity in African Solanaceae that can be used to address current and future needs regarding food and nutritional security in a long-term sustainable way (Schippers, 2002; Auguste *et al.,* 2014).

The best way to characterize and describe the specific character traits of landraces and cultivars is through morphological characterization (UPOV, 1991) and it is considered as the beginning of eggplant gene to phenotype relationship analysis and diversity structure. Characterizing traits morphologically also acts as a genetic guide in selection of germplasm for hybridization (Singh *et al.,* 2006) while broadening the genetic base of the cultivated eggplant varieties.

1.2 Problem statement and justification

African eggplant is among the most important indigenous vegetable crops in Africa. However, documented information on phenotypic characterization of local eggplant landraces and traditional varieties, maintained as ex-situ collections at the national gene banks, is limited (Keatinge *et al.*, 2012). Besides, the nutritional quality aspects of the African eggplant accessions have also received limited research attention. There is need to close existing knowledge and information gaps as increasing global attention is turned towards mobilizing local biodiversity for food nutrition and security. In addition, low water availability reduces eggplant production in Kenya and in many other African countries where crop production is mainly rainfed (Batiano *et al.,* 2007). Drought conditions are likely to worsen with time due to climate change which may lead to crop failure in these countries (Batiano *et al.,* 2007). There is therefore a need to identify eggplant accessions that are highly adapted to water stress. There are few studies on the impact of water stress on African eggplant in Kenya.

African eggplants, if improved, possess the potential to become a major source of income for a significant number of small-holder vegetable farmers and traders in both urban and rural areas. In general, there is a need to develop cultivars with high growth vigor, resistance to water stress, resistance to pests and diseases and with good consumer nutrient quality and shelf-life. Given the difficulties in meeting the nutritional needs of people in the developing world through fortification, supplementation and other western approaches, the study aimed at promoting development of germplasm that directly address nutrition through crop improvement. There is an urgent need for the active reintroduction of eggplant genetic diversity resources into the current production system in order to optimize their use and also protect the existing local cultivars and landraces from extinction (Caguiat and Hautea, 2014). Improvement and protection of the

indigenous eggplant varieties requires analysis of their traits, variation and relationship with the same accessions (Munoz *et al.,* 2008). The focus is on growing and selection of African eggplant germplasm that possess good qualities and have great impact on food security to most African countries if improved. Wild varieties also contain important genes that can be exploited in genetic improvement of cultivated eggplant varieties.

Morphological characterization of eggplant genetic resources will enable gene bank curators to identify accessions with desirable traits, monitor their genetic stability and integrity while screening for duplicate accessions to minimize wastage of resources and lower management costs (Collonnier *et al.,* 2001).

1.3 Objectives

The main objective of the study was to identify desirable traits in African eggplant accession which could be used in future crop improvement programs for cultivated eggplant varieties. The specific objectives of the study were:

1. To evaluate African eggplant accessions for morphological and agronomic traits

2. To determine the effect of water stress on growth, yield and nutritional quality of selected African eggplant accessions.

1.4 Hypotheses

1. There are no differences in morphological and agronomic traits among African eggplant accessions.

2. Water stress has no effect on growth and yield of African eggplant accessions.

3. Water stress has no effect on nutritional quality of African eggplant accessions.

CHAPTER TWO: LITERATURE REVIEW

2.1 Botany of eggplant

Eggplant belongs to the solanaceae family in the plant kingdom of the advanced order solanales and magnoliophyta division (Bremer *et al*., 2003). Solanaceae family includes ninety-one genera and about 2450 species that vary in morphology, habit, and ecology (Mabberley, 2008). The members of solanaceae family adapt well to various agro-ecological zones and are widespread all over the world (Knapp *et al.,* 2004). Their wide distribution facilitates high levels of morphological diversity at the cultivar, species and genera levels (knapp *et al*., 2004).

The eggplant is cultivated as an annual plant in temperate climate but it is actually a tropical perennial crop. Its growth varies with accession and environment with a minimum height of 40 cm and the tallest accession being 150 cm tall, most of the leaves were large and coarsely lobed with leaf breadth ranging from 5 to 10 cm while leaf length varied from 10 to 20 cm (Dauney, 2003; Auguste *et al.,* 2014). The eggplants that are not domesticated have large leaves over 15 cm broad and 30 cm long with a plant height of up to 225 cm. They have purple to white flowers with 5 lobed corollas, also called 5-merous (5 stamens, 5 sepals, 5 petals) and they have spiny stems. They mostly have yellow stamens but the round-fruited and globose cultivars have 6, 7 or 8 merous flowers. In cultivated eggplant the fruit can be as long as 30 cm which is exceptionally large compared to other wild types which can be less than 3 cm in breadth (Swarup, 1995; Hurtado *et al.,* 2012). Domestication, human selection, mutation, hybridization and natural inter-crossing have resulted in dramatic expansion in fruit size, colour and shape while decreasing fruit bitterness and leaf prickliness in each plant which resulted in extensive genetic and morphological diversity in African eggplant (Frary *et al.,* 2007). There is quantitative variation in anthocyanin pigmentation, hairiness and prickliness on vegetative parts. The leaves are large, hairy on the

underside and alternate on the stems. Leaf prickles and hairiness are more pronounced in wild types (Nonnecke, 1989; Jagatheeswari, 2014). The fruit of an eggplant is a fleshy berry that has colours ranging from black, white, green, shinny purple and yellow and the skin has stripes and patches (Dauney, 2003). The shape of fruits varies from round to oblong, cylindrical, long and oval in shape. Anthocyanin and chlorophylls (a and b) distribution pattern controls eggplant fruit colour diversity (Frary *et al.,* 2007). Kalloo (1993) describes the eggplant as a self-pollinated crop, but sometimes cross-pollination occurs. Parthenocarpy sometimes occur (Chen and Li, 1996; Boyaci *et al.,* 2011).

Stàgel *et al.,* (2008) describe eggplant *Solanum aethiopicum* as the African eggplant, *Solanum melongena* as the cultivated eggplant, *Solanum insanum* as a weedy form of eggplant in wild state and *Solanum incanum* as a close relative of the wild ancestors of eggplant (Sekara *et al.,* 2007). *Solanum melongena L*. is widely cultivated in tropics, subtropics and warm temperate regions and it's an economically important vegetable crop (Sihachakr *et al*., 1994; John, 2015). It is believed to have originated from south East Asia (Lester and Hasan, 1991; Doganlar *et al.,* 2014). The name "eggplant" most probably came from the egg like shape fruits of the Scarlet eggplant species (Kalloo, 1993; John, 2015).

The scarlet eggplant (*Solanum aethiopicum L*.) has been introduced to West Indies and South America, primarily Brazil but it is native to Africa (Daunay *et al.,* 2001; John, 2015). It has small white corollas and bright scarlet fruits which resemble capsicum peppers and distinguishes it from *Solanum melongena*. It is widely cultivated in South America and Africa. The humid tropics of central Africa is the native home of Gboma eggplant where its leaves and fruits are edible (Weese and Bohs, 2010).

The semi domesticated and wild eggplants are usually abundantly prickly and have round, small and yellow fruits. The brinjal eggplants are considered to be distantly related to *S. Macrocarpon* and *S. aethiopicum* (Frary *et al.,* 2007). Landraces, field weeds and wild plants making up the eggplant complexes are found in Middle East, India and Asia and they were originally distributed from Africa. The African taxa occupy habitats that are diverse ecologically and vary morphologically ranging from woodland savannas in equatorial regions to almost desert environments. Domestication of eggplant with big fruits started in India while the small fruited accessions started being grown in 4th and 9th century in China and Africa respectively (Sekara *et al.,* 2007). The Arabs brought eggplant to Iberian Peninsula and to North Africa before 10th century from Indo-Chinese center of origin and domestication (Prohens *et al.,* 2005; Sekara *et al.,* 2007). The Arabs later own introduced eggplant to the West in 15th century and from there it's cultivation slowly advanced from Mediterranean basin to Africa, Central Europe and then America (Kashyap *et al.,* 2003; Frary *et al.,* 2007).

Introgression of genes into commercial eggplant accessions was prevented by domesticating commercial eggplant in isolation from its wild accessions in Africa and near East. Despite the variation of the morphological traits due to genetic bottleneck suffered during evolution the results were considerably narrow genetic base in commercial eggplant varieties (Prohens *et al.,* 2005).

One third of the species within the genus *Solanum* is made up of subgenus *Leptostemonum* where eggplant belongs (Frary *et al.,* 2007). It has twelve chromosomes and it is a diploid species 2n=24 (Doganlar *et al.,* 2002a). Taxonomic confusion related to classification of the genus *Solanum* is based on the fact that more than 3000 binominal names have been used to describe 1000 to 1400 species (Furini and Wunder, 2003). Furini and Wunder (2003) explain the high level of

morphological plasticity manifested at the genera, species and cultivated levels in the eggplant composite.

2.2 Ecology and importance of the eggplant

Eggplants grow in different ecological zones from the temperate climatic conditions through to the tropical plains. Planting of different eggplant varieties should be selected to fit the climate conditions (Tsao and Lo, 2006). Eggplants take over six months growing time under warm climatic conditions to give mature and high fruit quality. Eggplant is grown under an average monthly temperature of 21 to 30^0C, with a minimum of 18^0C and a maximum of 35^0C. Eggplant seed germination requires an optimum soil temperature ranging from 24^0C to 32^0C. Experiencing cool weather for long periods affects the yield and quality of eggplant fruits, while high yield is achieved under high humidity and temperature (Frary *et al.*, 2007).

Eggplants do well in well-drained soils and prefer to grow in a site free from soil borne pest and diseases and that has not had crops from solanaceous family for at least two seasons (FAO, 2010). Eggplant grows in a wide range of soils because of their moderately deep rooting system. It does well on deep and free draining sandy loams or alluvial soils which are light-textured having a soil pH ranging from 6.0-7.0 (Chen and Li, 1996; Wang *et al.*, 2014).

Economically eggplant is ranked third in solanaceae family after potato and tomato in regards to its importance. Thirty two million tonnes of eggplant fruit is produced in the world (Houshna, 2009). The highest producers of eggplants in other parts of the world are Spain (0.2 million tons), Italy (0.3 million tons), Turkey (0.8 million tons), Egypt (1 million tons), India (8.4 million tons) and China (18 million tons) (FAOSTAT, 2007; Houshna, 2009). In 2013 the quantity of eggplants produced in Kenya for commercial purposes were 9,447 MT valued at Kshs 230 million (HCDA,

2013). The leading eggplant producing counties in Kenya were Makueni, TaitaTaveta and Kilifi counties contributing 21.8%, 16.2% and 14.2% respectively (HCDA, 2013).

2.3 Nutritional quality of eggplant

Eggplant fruits are characterized by low calorie content and high nutritional value. Kowalski *et al.* (2003) reported mean calorie value of eggplant fruit equal to 87 Kj. In 100 g of fresh matter there is 1–1.1 g of protein with 18 amino acids, 0.1–0.2 g of fat with linoleic acid as a dominant fatty acid, 5.7–6.3 g of total carbohydrates and 2.5–3.4 g cellulose (Kowalski *et al.* 2003; USDA 2010). Eggplant fruits have mineral salts of potassium, phosphorus, calcium and magnesium (Golcz *et al.,* 2005). Kowalski *et al.* (2003) also showed that eggplant fruits contain microelements, such as Zn, Fe, Mn, Cr, Cu and Se. These fruits also have precious components like choline, phytosterols, vitamin E and K, folic acid, omega 3 acid, omega 6 acid, β-carotene and pantothenic acid (Kowalski *et al*., 2003). Some of the most valuable components of the eggplant can be classified as phenolic acids and their derivatives which feature, among others, antioxidant activity. An eggplant contains considerable amount of anthocyanin, which provides for its high antioxidant value (Azuma *et al.,* 2008).

2.4 Constraints to eggplant production

The main constraints to eggplant production include: salinity, nutrient deficiencies, drought stress, water logging and excessive cold, frost and freezes. Crop production in arid and semi-arid regions is mainly affected by salinity and low precipitation which reduces leaching (Zhao *et al.,* 2007). FAO (2008) explains that more than 800 million hectares of world land is affected by either salinity or sodicity which is over 6% of the world's land. Osmotic inhibition of specific ion effect or the inhibition of water uptake by roots are some of the ways which salinity reduces plant growth, which affects cell division, cell expansion, and stomatal conductance (Munns, 2002; Abed El-

Azeem *et al.,* 2012). Eggplant production is affected by *Verticillium* wilt, *Phomopsis* blight, *Fusarium* and bacterial wilt (Monma *et al.,* 1997; Garibaldi *et al.,* 2005).

Solanum melongena rootstocks that are resistant to water logging and bacterial wilt were developed by Asian Vegetable Research and Development Center (AVRDC) for grafting tomato. Eggplants are susceptible to many types of pests such as fruit and shoot borer (Keshyap *et al.,* 2003).

Eggplants, like other plants, require nutrients for growth and development. The plants vary in production depending on soil pH. The most limiting nutrients in many African soils which affect crop production are nitrogen and phosphorus (Suge *et al*., 2011). Subsistence farming in sub-Saharan Africa is low because they mostly use soils that have low and declining fertility (Suge *et al*., 2011). The decline in soil fertility and increase in acidity has been mostly influenced by soil erosion and leaching, nutrient losses through harvest and continuous cropping with low or no fertilizer inputs (Suge *et al*., 2011)

Eggplant is very sensitive to cold temperatures because it reduces plant vigor and yields by stopping root growth development. Chilling injury caused by long periods of chilly but frostless weather affects young plants and unharvested fruits (Nothmann, 1986; Michelle, 2010). During the early stages of plant growth freezes and frosts are mainly very destructive to the young crop. The cold weather may cause the fruits to be misshaped (Nothmann, 1986; Michelle, 2010).

Low-lying areas of eggplant fields may easily be flooded by too much rain which negatively affects its production. In case of excess rainfall and waterlogging occurs eggplant roots can be suffocated causing wilting and finally death of plants. Brown discoloration in the stem interior and yellowing of the bottom leaves are the symptoms of excessive moisture damage to eggplant crops. Growth of rot pathogens is another symptom of prolonged periods of very wet conditions in eggplant fields.

Improving soil drainage is the only way to control damage of the crops from excessive moisture (Bauder, 2009).

2.4.1 Drought stress

Drought is a period of dry weather, especially a long one that is injurious to crops. Generally drought stress occurs when the available water in the soil is reduced and atmospheric conditions cause continuous loss of water by transpiration or evaporation (Martinez *et al.,* 2007). According to these authors, the types of drought stress include physical soil drought, physiological soil drought and atmospheric drought. Physical soil drought refers to shortage of water due to limited or non-availability of water from various sources like rainfall and irrigation while physiological soil drought occurs when water is available in plenty in the soil but the plants growing in such environment cannot be able to avail or absorb the water due to physiological reasons such as presence of excessive salts and pH alterations. Atmospheric drought occurs due to low atmospheric humidity, high wind velocity and high temperature which cause a plant to lose most of its water by transpiration, thus resulting in water deficit situations. Under normal and stress-free situations, the plant will exist in a soil moisture potential range between - 0.01 and -1.5 MPa (Nawamooz *et al.,* 2010). However, at permanent wilting point, the soil water potential will be between – 2.0 and – 4.0 MPa. At this point, leaf water potential will be still lower than the soil water potential (Nawamooz *et al.,* 2010).

Although eggplant is a warm season crop, low plant growth rate and bitter tasting fruits can be caused by dry condition and excessive heat (Azadeh *et al*., 2014). Eggplant fruit marketability is mostly reduced by sun scalding which is caused by extremely high temperatures during the drought. The most obvious effect of water stress is growth reduction, leading to less fresh and dry

biomass production (Azadeh *et al*., 2014). Drought stress causes closure of stomata and reduction in leaf area which translates to decline in photosynthetic pigments and activity (Amira, 2014).

The most limiting factor affecting crop production worldwide is water deficit (Nuruddin, 2001). Slow growing plants are associated to be growing under sub-optimal moisture levels and, in severe cases, dieback of stems such plants are less tolerant to insect attack and more susceptible to disease (Wilson, 2009). Reduced yields in eggplant production have been associated to water stress. The main consequence of inadequate moisture level for eggplant is decreased growth, development and production. Poor-quality eggplant results from long periods of hot, dry weather. It is very crucial to maintain the growth of plants by being able to recognize early symptoms of water stress which are wilting and the bottom leaves may turn yellow (Bauder, 2009).

Increase in foliage temperature, closure of stomata and decrease in transpiration are other symptoms of water on a crop (Tan and Buttery, 1982). Shifts in precipitation in an area will probably result in decreased soil water available to eggplants crop grown in that area (Keeling *et al.*, 2002). Drought stress led to increase in quantity of total soluble solids (Mahmoud *et al.*, 2012), it increased quantity of β-carotene (Helyes L. *et al.*, 2014) and it also increased vitamin C quantity in eggplant (Khan *et al.*, 2011). Drought stress on the other hand reduced the content of magnesium, iron, zinc and calcium nutrients (Nahar, 2002).

2.5 Methods of assessing phenotypic variation

Current methods of analyzing phenotypic diversity in segregating populations, germplasm accessions and breeder's lines rely on pedigree, morphological and agronomic performance (Bar-Hen *et al.*, 1995; Hamrick and Godt, 1997; Ogwu *et al.*, 2015). Morphological variation doesn't always show exact genetic variation due to the environment (E) and genotype (G) interaction and the unknown genetic control associated with agronomic, polygenic and morphological traits

(Smith and Smith, 1992; Ogwu *et al.*, 2015). Evolutionary biologists and plant ecologists mostly study genetic identities or patterns of phenotypic variation across variable environments. Scientifically, phenotypic traits change throughout the growth and development of specific plants and vary greatly within eggplant accession. Different environments cause different plant varieties to grow at different rates, and at a specific age they will be of different stages and sizes (Allendorf and Luikart, 2007). The methods of assessing phenotypic variations are pedigree data and characterization of crop species using agro-morphological characters.

2.5.1 Pedigree data

Pedigrees of varieties are defined as a thorough recording of relationships traced back to landraces and wild relatives. Pedigree analysis can be performed if the pedigrees of studied materials are known. Documentation and conservation of genetic identity of germplasm collection fulfils many utilization and curatorial needs, such as hybrids and pedigree for registration and commercial cultivation, determining varietal distinctiveness and safeguarding original types in germplasm repositories (Tiwari, 2007). Even though it is possible to examine genetic mechanisms without such data, using families, pairs of relatives, or even unrelated individuals, pedigree data provides the most genetic information.

2.5.2 Agro-morphological characters

Consumer preference for a variety of African eggplant is based mainly among others on size, form, colour and taste (sweet or bitter). The first step in the studies of genetic relationships in most breeding programmes is characterization of morphological traits (Osei *et al*., 2010). The evaluation of qualitative morphological traits is simple, rapid and inexpensive to score. Morphological characterization involves both primary and secondary characterization. Secondary characterization deals with more complicated morphological traits of agronomic importance such as fruit set,

disease and pest resistance, biochemical properties and yield potential, while primary characterization involves measuring simple plant character traits that can be easily recorded through visual observations at different plant growth stages (Ayad *et al*., 1995).

Selection of crop germplasm based on morphological characteristics is affected by errors caused by changes in the environmental conditions. Morphological appearance needs comprehensive trials to satisfactorily describe germplasm and the descriptions should be taken at the same location during the same season in order to bring about a valid comparison (Sunseri *et al*., 2010). The relationship of eggplant cultivars has been established and described using morphological characterization (Polignano *et al*., 2010; Sunseri *et al*., 2010; Adeniji *et al*., 2012, 2013).

Breeders can use evaluation of genetic resources to further improve the existing ones following consumer demands or challenges during growth conditions such as abiotic and biotic stress attributes (He *et al*., 2003). Selected landraces are scattered across the major agro-ecologies of Africa making it difficult to concentrate on the desirable traits required for genetic improvement of the crop (Osei *et al.*, 2010)

The European Genetic Resources Network (EGGNET) came up with the morphological descriptors used to characterize eggplant accessions. Genetic diversity of eggplant has also been studied using molecular markers (Prohen *et al*., 2008). Hierarchical clustering is performed using available morpho-agronomic data for a set of genotypes and a standard metric distance (such as the squared Euclidean), is computed and a clustering strategy, such as unweighted pair group or Ward method of arithmetic mean, is applied. Genotypes can be clustered into groups that are heterogeneous or homogeneous as possible using clustering strategies such as Unweighted Pair

Group Method with Arithmetic mean (UPGMA), centroid method, Ward method and single or complete linkage.

2.6 Measures of genetic variation

It is difficult to measure genetic diversity in quantitative traits because environmental factors influence the phenotype. Five processes that influence the distribution and amount of variation in population are: mutation, natural selection, migration, random genetic drift and non-random mating (Denver, 2006). Measures of genetic variation in each population level use two models: (i) "richness" of any population (or its sample) representing all the genotypes present in the population, and (ii) "evenness" or the frequency of different genotypes in the samples analyzed (Frankel *et al.* (1995).

Measures of average observed heterozygosity are used to determine the evenness of genotype frequencies. Heterozygosity is usually the most widespread measure of genetic variation within a population. Kaufman and Rousseeuw (1990) reported that Euclidean distance and square Euclidean distance are the most commonly used measures for morphological data to estimate genetic distance (GD) between individuals, whereas measurement of genetic distances between individuals on the basis of different types of characters such as qualitative and quantitative can be done using Gower's distance (Gower, 1971).

An index commonly used in the measurement of genetic variation is the 'Shannon's Index' or 'H' (Spellerberg, 1991), it can also be called the 'Shannon-Weaver' Index (Poole, 1974; Niklaus et al., 2001).

The Shannon-Weaver diversity index (H') is computed using the phenotypic frequencies to assess the phenotypic diversity for each character for all genotypes studied. Perry McIntosh (1991) described the Shannon-Weaver diversity index:

Equation 2.1

$$H' = 1 - \sum_{i=1}^{n} pi \ln$$

Where n is the number of phenotypic classes of traits while pi is the proportion of accessions in the i^{th} class of an n-class character. Each H' value is divided by its maximum value (log n) and normalized following an order thus keeping the values between 0 and 1. A monomorphic population has its minimum value of the index as zero. Due to increase in polymorphism the value of the index also increases until it reaches the maximum value (Yang *et al.,* 1991). The additive properties of 'H' are used to evaluate the diversity of characters within the population and the locations by pooling various characters across collection sites.

2.7 Measures of genetic distance

The difference between two genes being proportional to the time since they shared a common ancestor is genetic distance. Originally it was derived as a means to estimate the populations' degree of genetic differentiation. Some proposals have been made on the use of genetic distance for analysis of morpho-agronomic data to in order to come up with genetic diversity. Genetic distance is calculated following the data set by different statistical measures. Similarity indices measure the similarity between two individuals and the larger the value the more related two individuals are, while dissimilarity coefficient on the other hand estimates that if the distance or the difference of two individuals is bigger in values, that shows the more diverse the two individuals are (Kosman and Leonard, 2005).

2.8 Multivariate analysis

The order of genetic relationship among accessions can be clearly shown by multivariate analysis procedures. Accessions are characterized using morphological data from the growing plants. Multivariate analysis analyzes data using techniques, such as principal coordinate analysis (PCoA), multidimensional scaling (MDS), cluster analysis and principal component analysis (PCA) (Cruz and Carneiro, 2006).

2.8.1 Cluster analysis

Grouping units according to similarity for certain response patterns or characteristics is very important for studying relationships among closely related accessions which is also called clustering (Hair *et al*., 1995). It entails a ladder like procedure of calculating similarities and dissimilarities between observations and grouping together those that are most similar in hierarchy (Mutsaers *et al.*, 1997). There are two types of clustering methods: (i) model-based methods, here analysis from each cluster is derived from some parametric model, assumed to be unsystematic and standard statistical methods such as Bayesian methods and maximum-likelihood are used to equally perfume inferences about parameters closely related to each cluster and cluster association of each individual (Pritchard *et al*., 2000), and (ii) distance-based methods, here a specific clustering algorithm uses pair-wise distance matrix as an input for study (Johnson and Wichern, 1992).

Nonhierarchical and hierarchical make up the distance-based clustering methods. The nonhierarchical methods also referred to as K-means clustering measures do not occupy the structure of dendrograms and are based on chronological threshold (Everitt, 1980). Genetic diversity in crop species is mainly done using hierarchical clustering methods. Each observation is a “cluster” by itself. Within the first step the two most similar clusters are grouped together to

form a new cluster. Clusters are merged together step-by step this way until all observations (clusters) are grouped together to form one final cluster. Unweighted Pair Group Method with Arithmetic means is the most commonly used hierarchical method used followed by ward's minimum variance (Panchen, 1992). Furini and Wunder (2003) explain that inasmuch as the members of the eggplant aggregate, they can create enough genomic flexibility to adapt to various environmental changes.

Some characterization studies have been conducted on African eggplant. Osei *et al.* (2010) studied variations in growth and yield characteristics of 28 accessions of African eggplants. Three species of *Solanum aethiopicum* (16 accessions), *Solanum macrocarpon* (9 accessions) and *Solanum anguivi* (3 accessions) were characterized using standard morphological descriptors. The results indicated distinct and wide variations between the three *Solanum* species studied. There was a higher similarity between S. *aethiopicum* and S. *anguivi* lines. Clear variation was noticeable in fruit characteristics, both between and within species. *S. anguivi* accessions had small sized round fruits, while *S. aethiopicum* had medium to large sized oval fruits. Both *S. aethiopicum* and *S. anguivi* lines had few leaf hairs which were absent in lines belonging to *S. macrocarpon*.

2.8.2 Principal component analysis

Wiley (1981) defines principal component analysis (PCA) as a technique which uses mathematical principles which are sophisticated to transform a number of correlated variables which are possible into a smaller number of variables called principal components (PCs). Linear conversion of the original variables into a new set of uncorrelated variables called principal components. The total dissimilarity that is displayed on the PC axes is explained by PCA estimated eigenvalues. The first PC summarizes most of the unpredictability present in the original data relative to all residual PCs.

A second principal coordinate (axis) is obtained from the PCA method which is perpendicular to the first PC, and original data is approximated using that. The second step in the PCA describes most of the variability uncorrelated with the first PC and most variables that were not summarized by the first PC, and many more (Jolliffe, 1986).

2.8.3 Principal coordinate analysis

Principal coordinate analysis **(**PCoA) is an ordination technique that begins with a matrix of dissimilarities or similarities between a set of individuals and aims to create a low-dimensional graphical plot of the statistics in a way that distances between points in the plot are close to novel dissimilarities.

The positioning of objects in a space of reduced dimensionality while preserving their distance relationships is permitted by PCoA. PCA is superior to PCoA because in each point in PCA is placed exactly where it is supposed to be, while in PCoA each point is only approximated based on the dissimilarity model of best-fit. Rohlf (1972) recognized that the treatment of missing information is not reasonable in PCA as compared PCoA which is more reasonable.

2.8.4 Multidimensional scaling

Multidimensional scaling (MDS) is a procedure that represents a set of genotypes *(n)* or individuals in a few dimensions *(m)* using a similarity/distance matrix between them (Johnson and Wichern, 1992). There are two types of MDS: (i) non-metric MDS, which is used when the inter-individual proximities in the map nearly match the original similarities/distances, and (ii) metric MDS, helpful when the real scales of original similarities/distances are used to get an arithmetical representation in *m* dimensions (Johnson and Wichern, 1992). Numerical measures of closeness called “stress”, is commonly tested and it shows the percentage of the variance of the disparities not accounted for by the MDS.

Rohlf (1972) reported that the actual arrangement of individuals consequential from MDS, PCA, and PCoA are typically related. On the contrary, results based on MDS contrast with PCA and PCoA since (i) differences among close individuals are, in common, reflected better by MDS, and (ii) the smaller or greater distances among individuals are not essentially represented by MDS to the equivalent scale. MDS is preferable over PCA and PCoA when the number of individuals is large; when there are no missing data PCA is preferred while PCoA is used when there are missing data (Rohlf, 1972).

CHAPTER THREE: EVALUATION OF AFRICAN EGGPLANT ACCESSIONS FOR MORPHOLOGICAL AND AGRONOMIC TRAITS

3.1 Abstract

The African eggplant is among the most important indigenous horticultural crops in Africa. However, there is limited information on its morphological and agronomic traits. A systematic characterization of the existing African eggplant accessions is therefore required to promote its improvement. Field and greenhouse experiments were conducted at the University of Nairobi's Field Station during 2014 and 2015 long and short rain seasons, respectively, to evaluate the morphological and agronomic traits of the collected accessions of African eggplant. Seventy-two accessions from four species namely *Solanum aethiopicum* (50 accessions), *Solanum macrocarpon* (1 accession), *Solanum anguivi* (6 accessions) and *Solanum* sp (15 accessions) were characterized based on the available African eggplant descriptors list. Both field and greenhouse experiments were laid out in a randomized complete block design with three replications. Data were collected on nine quantitative (plant height, leaf length, leaf width, fruit length, fruit breadth, fruit weight, number of fruits per plant, chlorophyll content and days to 50% flowering) and eight qualitative traits (growth habit, leaf prickles, leaf hairs, fruit breadth, fruit length, flower colour, fruit shape and fruit position) measured at flowering and fruit maturity stages. The analysis of variance indicated significant differences ($P<0.05$) for most of the accessions grown in the field and greenhouse. Fruit length was significantly ($P<0.05$) and positively correlated with fruit breadth ($r = 0.59$ and 0.60), fruit weight ($r =0.72$ and 0.73) and leaf blade width ($r =0.34$ and 0.28 for field and greenhouse grown accessions, respectively). However, fruit length correlated negatively but highly significantly with the number of fruits per plant ($r = -0.32$ and -0.31 for field and greenhouse grown accessions, respectively). On the other hand fruit length was positively correlated with leaf

blade length (r = 0.09 and 0.09) and plant height (r = 0.15 and 0.16) while days to flowering had a positive correlation with SPAD value (r = 0.08 and 0.06), respectively, for field and greenhouse grown accessions. Cluster analysis placed the accessions into two cluster groups with cluster I having 51 accessions and cluster II having 21 accessions. Both in the field and greenhouse, 87.5% of the accessions showed an upright growth, intermediate growth habit (9.7%) and prostrate growth habit (2.8%). Accessions with leaf prickles and leaf hairs were 68.1% and 70.8% respectively. Shannon-Weaver diversity index (H') estimates for the qualitative characters in the field and greenhouse were high (H'>0.750). Principal component analysis showed that fruit parameters (fruit breadth and fruit position), flower parameter (flower colour) and leaf parameters (leaf hairs and leaf prickles) were important traits which distinctively separated the eggplant accessions. The results showed high yielding in accessions RV100200, GBK050572, RV100456, RV100256 and RV100239 while the lowest yield was seen in accession RV100335. African eggplant accessions varied in morphological growth and fruit yields. The key traits identified were plant height, fruit size, fruit weight, leaf size, leaf prickles and leaf hairs.

3.2 Introduction

African eggplant is one of the indigenous vegetables that plays a significant role in both subsistence production and income generation among rural and urban resource poor communities in Africa (Chadha, 2006; Msogoya *et al.*, 2014). Fruit colour, shape, size and flavor are the most perceivable quality attributes of African eggplant fruits (Hornal *et al.*, 2007; Msogoya *et al.*, 2014). Commercial eggplant is widely grown in America, Africa, Europe and Asia (Sekara *et al.*, 2007). Studies show that China is the leading country in eggplant annual production (27382464.19 MT) followed by India (11806465.08 million MT), Egypt (1376743.56 MT), Turkey (944923.63 MT), Indonesia (538504.86 MT) and USA (71123.28 MT) (Shakeel *et al*., 2015). In 2013 eggplant

production in Kenya was estimated at 9,447 MT valued at Kshs 230 million. The leading counties producing eggplants are Makueni, TaitaTaveta and Kilifi counties contributing 21.8%, 16.2% and 14.2%, respectively (HCDA, 2013).

The global interest in development of African eggplant has encouraged interest to call for germplasm collection and preservation. Characterization and evaluation of plant germplasm is imperative for categorization of germplasm and identification of desirable genotypes for utilization in breeding programs (Upadhyaya *et al.,* 2007; Shakeel *et al*., 2015). It is essential to collect data regarding the characteristics and variety of eggplant genetic resources for the sake of developing strong and effective eggplant breeding programmes (Sekara *et al*., 2007). Rodriguez-Burruezo *et al*. (2008) found out that, in open field cultivation, using germplasm accessions as parents the resultant eggplant hybrids were competitive in production when compared with commercial hybrids. Moreover, it also helped to build up the biodiversity. Chattopadhyay *et al*. (2011) performed characterization of 35 diverse brinjal genotypes which showed highly significant variations among 12 quantitative traits. Furini and Wunder (2004) characterized 94 *Solanum* accessions morphologically and found that morphological parameters were helpful in assessing similarities or differences among accessions. As part of a crop-improvement strategy, a collection of genus '*Solanum*' germplasm is being maintained at the gene banks of the Asian Vegetable Research and Development Center (AVRDC) in Arusha Tanzania and Muguga in Kenya. The germplasm is from wild and exotic collections with little information on the level and kind of diversity present in the maintained collection. Thus, morphological and agronomic characterization of these germplasm lines is considered important for improvement, conservation and future utilization of the African eggplant. It is very critical to assess the relative magnitude of genetic variability, nature and extent of character association with yield and its related characters

for sound breeding programs. The utility of multivariate analysis for measuring the degree of genetic divergence and for assessing the relative contribution of different characters to the total divergence in self and cross pollinated crops has been established by several researchers (Uddin, 2014). The objective of the current study was to evaluate 72 African eggplant accessions for morphological and agronomic traits.

3.3 Materials and Methods

3.3.1 Site Description

Field and glasshouse experiments were conducted at the University of Nairobi's Kabete field station, Kenya. The site is located on the latitudes 1^0 14′ 20″ to $1^0$15′15″ south and longitudes 36^0 44′ to 36^0 45′ east, at an altitude of 1940 meters above sea level. The agro-ecological zone of the area is upper midland (UM) Zone three (Jaetzold and Schmidt, 1983). The site receives bimodal rainfall averaging 1000 mm annually. The long rains occur from early March to late May, whereas short rains occur from October to December. The site has minimum and maximum mean annual temperature of 13 and 23^0C, respectively (Siderus, 1976). Kabete soils are classified as humic nitisols according to FAO (1990). They are deep, well drained, dark reddish, deep friable clay type resistant to erosion (Michieka, 1978). Crops grown in the area include tomatoes, potatoes, eggplant, maize and beans. The study was carried out in the long rains and short rainy season of 2014 to 2015 respectively. Soils were sampled at 30 cm depth prior to planting and analyzed for soil pH, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, manganese, copper, iron, zinc, sodium and electrical conductivity at the Kenya Agricultural and Livestock Research Organization (Table 3.1).

Table 3.1: **Soil chemical characteristics of the experimental site (University of Nairobi, Kabete Field Station)**

Parameters	Value	Critical level
Soil pH	7.0	< 5.0
Total nitrogen %	0.3	< 3.0
Total organic carbon%	2.7	< 0.5
Phosphorus(ppm)	149.0	< 0.3
Potassium (me %)	0.4	< 0.75
Calcium (me %)	11.7	< 1.0
Magnesium (me %)	8.2	< 0.4
Manganese (me %)	0.8	< 2.3
Copper(ppm)	8.5	< 4.0
Iron (ppm)	82.3	< 30.0
Zinc (ppm)	31.3	< 25.0
Sodium (me %)	0.4	< 0.5
Electrical conductivity (mS/cm)	0.6	< 1.1

Ppm- parts per million; me- milligram equivalents per 100 g soil

3.3.2 Planting materials

Seventy two (72) African eggplant accessions from four species of *Solanum aethiopicum* (54), *Solanum macrocarpon* (1), *Solanum* sp (15) and *Solanum anguivi* (6) were used in this study. Seventy one (71) of the accessions were sourced from the Asian Vegetable Research Development Centre (AVRDC) based in Arusha Tanzania and Taiwan. One breeder's line eggplant accession was sourced from the National Gene Bank of Kenya in Muguga. The respective gene banks have coded the accessions as shown in Table 3.2.

Table 3.2: List of plant materials provided by AVRDEC-ESA

S/no	RVI code	Genus	Species	Name	Source
1	RVI00161	*Solanum*	*aethiopicum*	Manyire Green	Tanzania
2	RVI00342	*Solanum*	*aethiopicum*	Ofariwa'a	Cameroon
3	RVI00169	*Solanum*	*aethiopicum*	Tengeru white	Tanzania
4	RVI00356	*Solanum*	*anguivi*	UG-AE-1	Uganda
5	RVI00359	*Solanum*	*anguivi*	UG-AE-7	Uganda
6	RVI00360	*Solanum*	*anguivi*	UG-AE-8	Uganda
7	RVI00380	*Solanum*	*aethiopicum*	AB2	Ghana
8	RVI00445	*Solanum*	Species	S0004	Unknown
9	RVI00453	*Solanum*	Species	S00052	Unknown
10	RVI00449	*Solanum*	Species	S000735	Unknown
11	RVI00455	*Solanum*	Species	S00047A	Unknown
12	RVI00456	*Solanum*	Species	MM813	Unknown
13	RVI00240	*Solanum*	*aethiopicum*	101	Mali
14	RVI00241	*Solanum*	*aethiopicum*	102	Mali
15	RVI00242	*Solanum*	*aethiopicum*	103	Mali
16	RVI00243	*Solanum*	*aethiopicum*	104	Mali
17	RVI00250	*Solanum*	*aethiopicum*	106	Mali
18	RVI00260	*Solanum*	*aethiopicum*	116	Mali
19	RVI00261	*Solanum*	*aethiopicum*	117	Mali
20	RV100262	*Solanum*	*aethiopicum*	118	Mali
21	RVI00263	*Solanum*	*aethiopicum*	119	Mali
22	RVI00264	*Solanum*	*aethiopicum*	120	Mali
23	RVI00265	*Solanum*	*aethiopicum*	21	Mali
24	RVI00328	*Solanum*	*aethiopicum*	Local mali	Mali
25	RVI00458	*Solanum*	Species	S001381	Unknown
26	RVI00200	*Solanum*	*aethiopicum*	GKK-AE-150	Malawi
27	RVI001201	*Solanum*	*aethiopicum*	GKK-AE-158	Malawi
28	RVI00234	*Solanum*	*aethiopicum*	70	Mali
29	RVI00246	*Solanum*	*aethiopicum*	112	Mali
30	RV100249	*Solanum*	*aethiopicum*	115	Mali
31	RVI00252	*Solanum*	*aethiopicum*	108	Mali
32	RVI00266	*Solanum*	*aethiopicum*	22	Mali
33	RVI00325	*Solanum*	*aethiopicum*	Keurmbirndao	France
34	RVI00327	*Solanum*	*aethiopicum*	Aubergine B	Mali
35	RVI00332	*Solanum*	*aethiopicum*	RNL-187-194	Burkina Faso
36	RV100335	*Solanum*	*anguivi*	Tombout	Cameroon

Table 3.2: List of plant materials provided by AVRDEC-ESA

S/no	RVI code	Genus	Species	Name	Source
37	RVI00346	*Solanum*	*aethiopicum*	RW-AE-5	Rwanda
38	RVI00352	*Solanum*	*aethiopicum*	RW-AE-13	Uganda
39	RVI00364	*Solanum*	*anguivi*	UG-AE-20	Uganda
40	RVI00382	*Solanum*	Species	Bory bory	Madagascar
41	RVI00431	*Solanum*	Species	Lushoto	Tanzania
42	RVI00432	*Solanum*	Species	N4	Unknown
43	RVI00447	*Solanum*	Species	S00022-1	Mali
44	RVI00270	*Solanum*	*aethiopicum*	86	Mali
45	RVI00271	*Solanum*	*aethiopicum*	87	Mali
46	RVI00273	*Solanum*	*aethiopicum*	89	Mali
47	RVI00274	*Solanum*	*aethiopicum*	90	Mali
48	RVI00334	*Solanum*	*aethiopicum*	SOXNA	Mali
49	RVI00166	*Solanum*	*aethiopicum*	TZSMN67	Tanzania
50	RV100300	*Solanum*	*aethiopicum*	Local gaya	Mali
51	RVI00386	*Solanum*	*aethiopicum*	Ex-ivory coast	Ivory Coast
52	RVI00452	*Solanum*	Species	S0005	Unknown
53	RVI00333	*Solanum*	*aethiopicum*	Sangawili	Mali
54	RVI00377	*Solanum*	*aethiopicum*	Ex-sirongwo	Uganda
55	RVI00199	*Solanum*	Species	Ex-dar	Tanzania
56	RVI00190	*Solanum*	*anguivi*	N19	Tanzania
57	RVI00343	*Solanum*	*Macrocarpon*	CN012	Cameroon
58	RVI00236	*Solanum*	*aethiopicum*	2	Mali
59	RVI00239	*Solanum*	*aethiopicum*	5	Mali
60	RVI00438	*Solanum*	*aethiopicum*	MM1308	Unknown
61	RVI00185	*Solanum*	*aethiopicum*	MM803	Gabon
62	RVI00215	*Solanum*	*aethiopicum*	81	Mali
63	RVI00217	*Solanum*	*aethiopicum*	83	Mali
64	RVI00218	*Solanum*	*aethiopicum*	84	Mali
65	RVI00247	*Solanum*	*aethiopicum*	113	Mali
66	RVI00163	*Solanum*	*aethiopicum*	TZSMN57	Tanzania
67	RVI00259	*Solanum*	*aethiopicum*	55	Senegal
68	RVI00511	*Solanum*	*aethiopicum*	Sengerema	Tanzania
69	RVI00268	*Solanum*	*aethiopicum*	24	Mali
70	RVI00331	*Solanum*	*aethiopicum*	L10	Unknown
71	GBK 050572	*Solanum*	*aethiopicum*	Mafwa	Kenya
72	RVI00248	*Solanum*	*aethiopicum*	114	Senegal

RVI-Accession registration code used in AVRDEC, B-blanch

3.4 Experimental design and crop husbandry

3.4.1 Field experiments

Afield experiment was set up with 72 African eggplant accessions using a randomized complete block design with three replications. The experiments were carried out in two seasons (July 2014 to October 2014 and March 2015 to June 2015). The eggplant accessions were originally sourced from Mali (33), Tanzania (8), Uganda (6), Cameroon (3), Malawi (2), Senegal (2), Ghana (1), France (1), Burkina Faso (1), Rwanda (1), Madagascar (1), Ivory Coast (1), Gabon (1) and Kenya (1). Ten accessions were from unknown countries. The field was ploughed and harrowed with a tractor followed by fine hand ploughing. Experimental plot size was 13.8 m x 105 m. The blocks and plots were separated by 1m path each. Seedlings of each accession were planted in two rows at the rate of eight seedlings per row (16 plants in a plot). Inter-row spacing of 80 cm and intra-row spacing of 50 cm were adopted. The eggplant seeds were first sown in germination trays containing peat moss germination media and allowed to grow for four weeks before transplanting the seedlings. Two handfuls of well decomposed manure (equivalent to 392.05 grams) and one teaspoon (equivalent to 9.8 grams) of compound fertilizer N: P: K (23:23:0) per plant hole were thoroughly mixed with soil before planting the seedling. The eggplants were then top dressed with 250 kg/ ha of calcium ammonium nitrate (CAN) and when the plants were 25 cm high they were top dressed with 500 kg/ha of CAN six weeks later. The plants were sprayed with Actara® (active ingredient thiomethoxam), Karate® (active ingredient lambda cylothrin) and Ortiva® (active ingredient 250 g/l azoxystrobin) insecticides at the rate of 20 g per 20 litres of water against it at emergence, vegetative stage and before flowering to control white flies, thrips and aphids. Hand weeding was done frequently thus keeping the crop field weed free. Supplemental overhead

irrigation was applied whenever there was delay in rainfall and plants showed signs of water stress. Harvesting was done when the fruits attained commercial ripeness stage.

3.4.2 Greenhouse experiments

Seventy two (72) accessions of African eggplant were evaluated in pots in a greenhouse using a randomized complete block design with three replications. Two seedlings were raised per pot but thinned to one seedling per pot when the plants were 25 cm tall. The pots used were 36.5 cm long x 18.5 cm wide. The soil used in this experiment was collected at Kabete Field station in a land that had been left fallow for some time. The soil was then sterilized at 105^0C for 72 hours. One part of sand was mixed with two parts of soil and two parts of compost (ratio 1: 2: 2) before filling in the pots. The 72 pots per replication were each filled with 7 kg of air-dried soil mixture each. One teaspoon (equivalent to 9.8 grams) of calcium ammonium nitrate (CAN) fertilizer (23:23:0) was applied just before sowing per plant. Seedlings that had been germinated in trays and raised for four weeks were then transplanted into the pots. Watering was done using a watering can before and after transplanting of the seedlings. The plants were then top dressed with one teaspoon (equivalent to 9.8 grams) of calcium ammonium nitrate (CAN) per plant when the plants were 25 cm high and six weeks later top dressed with two teaspoons (equivalent to 19.6 grams) per plant of CAN. The plants were sprayed with Actara® (active ingredient thiomethoxam), Karate® (active ingredient lambda cylothrin) and Ortiva® (active ingredient 250 g/l azoxystrobin) insecticides at the rate of 20 g per 20 litres of water to control whiteflies, thrips and aphids at emergence, vegetative stage and before flowering. Pots were kept weed free by hand weeding.

3.5 Data collection

3.5.1 Morphological data

Four plants of each accession were randomly selected in each plot in the field and tagged. Since there was one plant per pot in the greenhouse there was no tagging as each plant in each pot represented an accession. Plants with high vigour were tagged at flowering to facilitate collection of data for both morphological and agronomic traits. Eight qualitative traits, namely plant growth habit, leaf prickles, leaf hairs (lower surface), flower colour, fruit shape, fruit position, fruit length and fruit breadth were characterized based on the list of modified eggplant descriptors FAO (IBPGR, 1990) as shown in (Table 3.3). Here the fruit length and breadth were represented by descriptor codes unlike in agronomic data where their measurements were noted. All observations for each character were made on the same day for all accessions after 50% flowering.

3.5.2 Agronomic data

Quantitative data were collected in the field and greenhouse for nine agronomical characters which included: plant height, leaf blade length, leaf blade width, fruit length, fruit breadth, fruit weight, number of fruits per plant, days to 50% flowering and SPAD (chlorophyll content). Unlike in morphological data here the fruits were measured and their actual fruit length and fruit breadth were used in the analysis not the descriptor codes. All measurements and counts of a given trait were done on the same day for the field and greenhouse grown accessions in order to maintain uniformity.

Table 3.3: Character, descriptor and codes used for characterization of African eggplant

Morphological data descriptors		
S/NO	Character	Descriptor and code
1	Plant growth habit	3-7 (3=upright, 5=intermediate, 7=Prostrate)
2	Leaf prickles	0-7 (0=none, 7=many)
3	Leaf hairs (lower surface)	1-9 (1=very few‹20, 9=very many›200)
4	Flower (corolla) colour	1-9 (1=greenish white, 3=white, 5=pale violet,7=light violet, 9=bluish violet)
5	Fruit shape	1-5 (1=round, 5=long)
6	Fruit position	1-9 (1=Erect, 3=Semi erect, 5=Horizontal, 7=Semi pendant, 9=pendant)
7	Fruit breadth	1-9(1= Very small ‹1cm, 3= Small~2cm, 5=Intermediate~3cm, 7=Large~5cm, 9=very large›10cm)
8	Fruit length	1-9 (1= Very short ‹1cm, 3= Short~2cm,5=Intermediate ~5cm, 7=Long~10cm, 9=very long›20cm)

Source: Food and Agriculture Organization of the United Nations (IBPGR 1990). Numbers in brackets on the right-hand side are the corresponding descriptor codes listed in FAO publication with a little modification during the development of the list

3.5.2.1 Growth components

Days to flowering was recorded as the number of days from raising the seedlings in the trays to when 50% of the plants in each plot or pot had flowered. The chlorophyll content was taken at 50% flowering on a fully expanded young leaf from four plants in each stand and averaged. Chlorophyll content was taken using a non-destructive, hand-held chlorophyll meter referred to as Soil Plant Analysis Development (SPAD-502, Minolta Camera Co., Ltd., Japan). SPAD-502 determines the relative amount of chlorophyll present in the leaf by measuring the transmittance of the leaf in two wave bands (600 to 700 nm and 400 to 500 nm). Chlorophyll has two absorbance peaks in the blue (400-500 nm) and red (600-700 nm) regions, with no transmittance in the near-infrared region. SPAD-502 measures the absorbance of the leaf in the red and near-infrared regions. Using these two transmittances, the meter calculates a numerical SPAD value, ranging

from 0 to 80 which are usually proportional to the amount of chlorophyll present in the leaf (Jarvis, 2008). Plant height was measured in centimeters from the base of the plant to the tip of the main stem using a meter rule by selecting four plants at random in the plot that were tagged, and their vertical heights measured after 50% flowering. Four basal leaves in each of the four tagged plants per plot were randomly selected at flowering and leaf measurements recorded. Leaf blade length (cm) was determined by measuring the length of the leaves found at the middle level of the four tagged plants. Leaf blade width (cm) was determined by measuring the widest part of leaves found at the middle level of the four tagged plants. Fruit length (cm) was measured using a Vernier caliper and the mean of four fruits calculated at fruit ripening stage. Fruit breadth (cm) was determined by cutting four fruits in half and their diameter measured using a vernier caliper and then the mean of the diameter of the four fruits was taken.

3.5.2.2 Yield and yield components

Fruit weight in grams was determined using a weighing balance by weighing four fruits per a tagged tree and their average taken. Number of fruits per plant was determined by counting all the fruits in the four tagged plants and taking the average.

3.6 Data analysis

3.6.1 Qualitative traits

Phenotypic frequency distributions of the characters were calculated for all accessions based on the Shannon-Weaver diversity index (‘H’) as explained by Perry and McIntosh (1991). Dissimilarities were approximated based on Euclidian distance matrix and hierarchical clustering analyses of unweighted pair group method of arithmetic mean performed in DARwin 6.0 software as described by Perrier and Jacquemoud-collet (2006). The clusters and relationships were displayed as a phenogram. Multivariate-principal component analysis (PCA) was conducted

between variance-covariance matrix using Genstat software programme, version 14 (Payne *et al.*, 2011) to identify the most significant descriptors in capturing the morphological variation in the germplasm.

3.6.2 Quantitative traits

Analysis of variance (ANOVA) for the quantitative data was performed using Genstat version 14 (Payne *et al.,* 2011) at 5% level of significance. Mean separation for treatment effects that were significant was done by Fisher's protected least significant difference (LSD) test using Genstat version 14 (Payne *et al.,* 2011). Variability within each quantitative trait was calculated using statistical measures of mean, standard deviation and coefficient of variation. A correlation analysis was performed in Genstat to estimate quantitative relationships among the traits and also to determine key agronomic traits of importance in breeding work.

3.7 Results

3.7.1 Qualitative characteristics

3.7.2 Growth habit

In both the field and greenhouse experiments, 87.5% of the accessions produced an upright growth habit, 9.7% intermediate growth habit and 2.8% prostrate growth habit (Table 3.4, Table 3.5 and Figure 3.1). Accessions with intermediate growth habit were RV100270, RV100274, RV100331, RV100386, RV100481, RV100445 and RV100449. While some of the accessions with prostrate growth habits were RV100271 and RV100360.

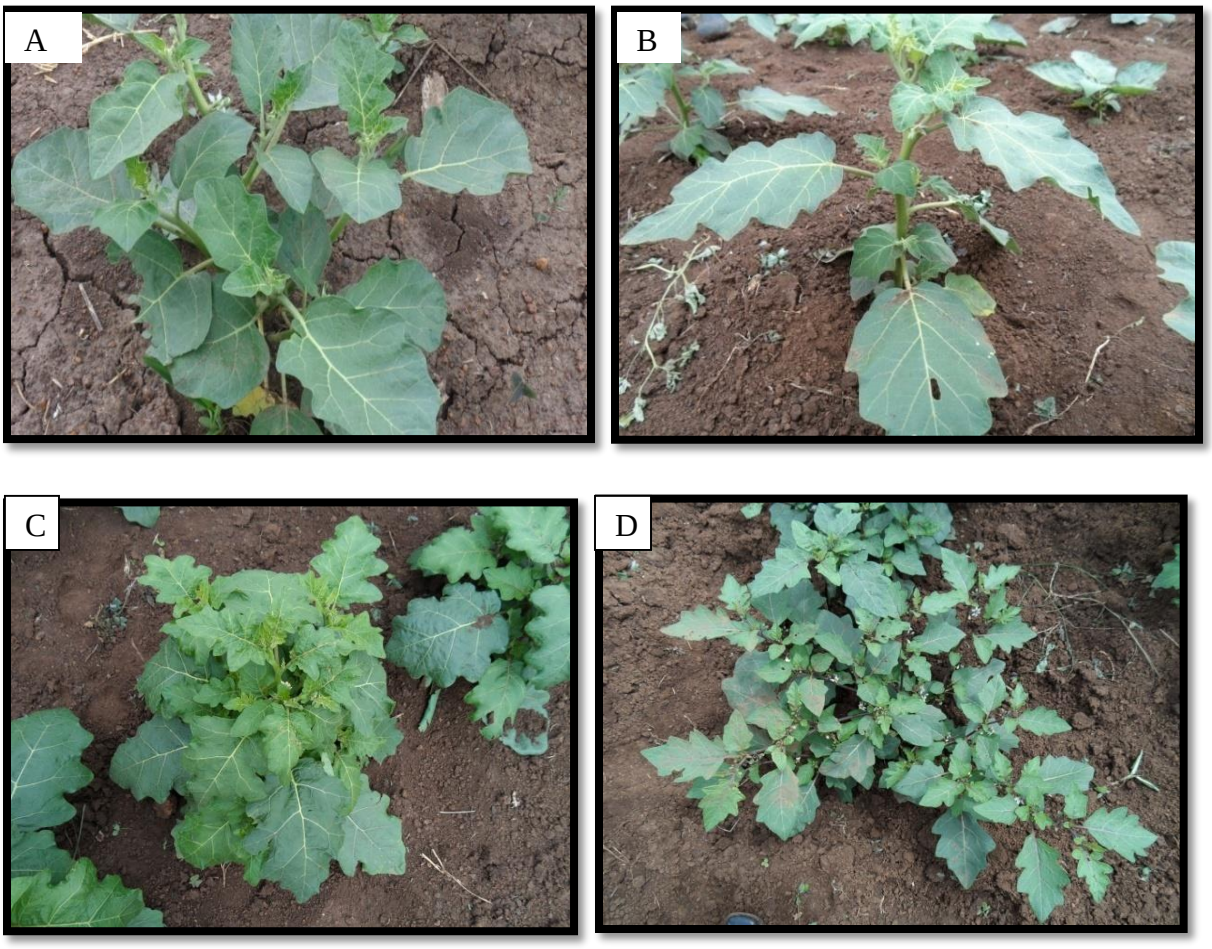


Figure 3.1: (A) Accession RV100333: Intermediate, green stem and leaf hairs; (B) Accession RV100342: green stem, upright plant growth and leaf hairs; (C) Accession RV100263: intermediate growth habit, long leaves and wide leaves; (D) Accession RV100360: Prostrate growth habit and small leaves.

3.7.2 Flower colour

In both the field and greenhouse experiments, 87.5% produced white flowers, 6.94% produced pale violet flowers, 2.8% produced light violet flowers, 1.4% produced bluish violet flowers and 1.4% produced greenish white flowers (Table 3.4, Table 3.5 and Figure 3.2).

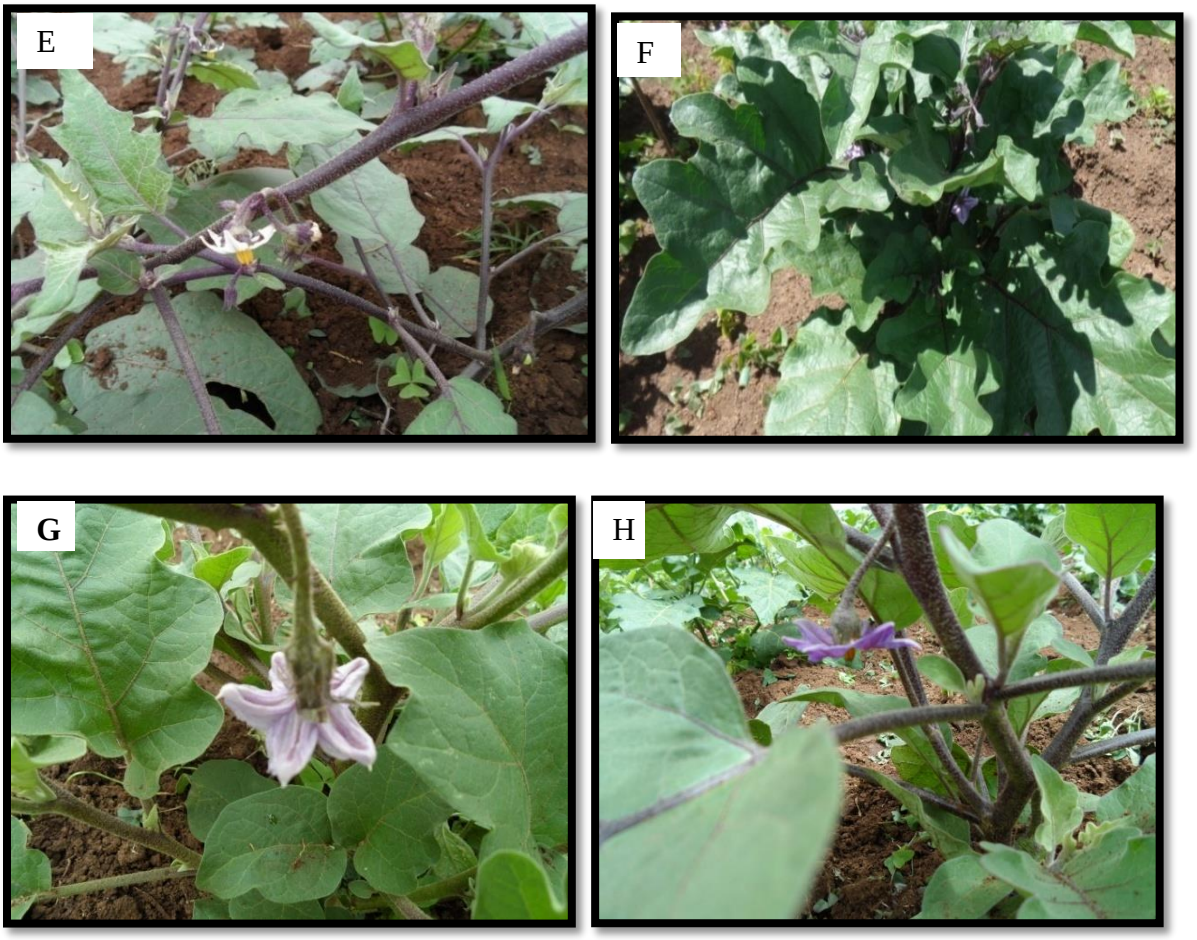


Figure 3.2:(E) Accession RV100431: white flowers, purple stem and leaf hairs;(F) Accession RV100455: Pale violet flowers, leaf hairs, long and wide leaves;(G) Accession RV100200: Leaf hairs, light violet flowers, long and wide leaves; (H) Accession RV100331: pale violet flowers, Leaf hairs, long and wide leaves.

Table 3.4: Morphological descriptors of 72 African eggplant accessions grown in the field

AC. CODE	P.G.H	L.P	L.H	F.C	FR.SH	FR.P	F.L	F.B
GBK 050572	Upright	Many	Very many	Pale violet	Long	Pendant	Long	Large
RV1001201	Upright	Many	Very many	Pale violet	Long	Pendant	Long	Large
RV100161	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100165	Upright	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100169	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100185	Upright	Many	Very many	White	Round	Semi pendant	Intermediate	Large
RV100190	Upright	None	Very few	White	Round	Semi pendant	Short	Small
RV100194	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100199	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100200	Upright	None	Very many	Pale violet	Long	Pendant	Intermediate	Intermediate
RV100215	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100217	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100218	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100234	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100239	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100240	Upright	None	Very many	White	Round	Horizontal	Long	Large
RV100241	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100242	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100243	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100246	Upright	Many	Very many	White	Round	pendant	Intermediate	Large
RV100248	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100249	Upright	None	Very many	White	Round	Pendant	Intermediate	Large
RV100250	Upright	Many	Very many	White	Round	Horizontal	Long	Large
RV100252	Upright	Many	Very many	White	Round	Semi erect	Long	Large
RV100259	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100260	Upright	None	Very many	White	Round	Pendant	Intermediate	Large
RV100261	Upright	Many	Very many	White	Round	Pendant	Short	Intermediate
RV100262	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100263	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100264	Upright	None	Very many	White	Round	Horizontal	Long	Large
RV100265	Upright	None	Very few	White	Round	Semi erect	Short	Small
RV100266	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100268	Upright	None	Very many	Light violet	Round	Pendant	Intermediate	Large
RV100270	Intermediate	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100271	Prostrate	None	Very few	White	Round	Pendant	Short	Small
RV100273	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100274	Intermediate	None	Very few	Greenish white	Round	Pendant	Short	Small
RV100300	Upright	None	Very few	White	Round	Pendant	Short	Small
RV100325	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate

Table 3.4: Morphological descriptors of 72 African eggplant accessions grown in the field

AC.CODES	P.G.H	L.P	L.H	F.C	FR.SH	FR.P	F.L	F.B
RV100331	Intermediate	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100327	Upright	None	Very many	White	Round	Pendant	Intermediate	Large
RV100328	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100332	Upright	Many	Very many	Light violet	Round	Semi erect	Long	Large
RV100333	Upright	None	Very many	White	Round	Pendant	Short	Intermediate
RV100334	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100335	Upright	None	Very few	White	Round	Pendant	Short	Small
RV100342	Upright	Many	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100343	Upright	None	Very few	White	Round	Pendant	Short	Small
RV100346	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100352	Upright	None	Very many	Pale violet	Round	Pendant	Intermediate	Large
RV100356	Upright	None	Very few	White	Round	Semi pendant	Short	Small
RV100359	Upright	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100360	Prostrate	None	Very few	White	Round	Pendant	Short	Small
RV100364	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100377	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100380	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100382	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100386	Intermediate	None	Very many	White	Round	Semi pendant	Intermediate	Large
RV100431	Intermediate	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100432	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100438	Upright	None	Very many	White	Long	Horizontal	Long	Large
RV100438	Upright	Many	Very many	White	Long	Pendant	Long	Large
RV100445	Intermediate	Many	Very many	Bluish violet	Long	Pendant	Long	Large
RV100447	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100449	Intermediate	Many	Very many	White	Round	Pendant	Intermediate	Large
RV100452	Upright	Many	Very few	White	Round	Pendant	Short	Small
RV100453	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100455	Upright	Many	Very many	Pale violet	Long	Pendant	Intermediate	Intermediate
RV100456	Prostrate	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100511	Upright	None	Very many	White	Long	Pendant	Intermediate	Intermediate

P.G.H-plant growth habit, L.P-Leaf prickles, L.H-Leaf hairs, F.C-Flower colour, FR.SH-Fruit shape, FR.P-Fruit position

F.L-Fruit length, F.B-fruit breadth

Table 3.5: Morphological descriptors of 72 African eggplant accessions grown in the greenhouse

AC.CODES	P.G.H	L.P	L.H	F.C	FR.SH	FR.P	F.L	F.B
GBK 050572	Upright	Many	Very many	Pale violet	Long	Pendant	Long	Large
RV1001201	Upright	Many	Very many	Pale violet	Long	Pendant	Long	Large
RV100161	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100165	Upright	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100169	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100185	Upright	Many	Very many	White	Round	Semi pendant	Intermediate	Large
RV100190	Upright	None	Very few	White	Round	Semi pendant	Short	Small
RV100194	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100199	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100200	Upright	None	Very many	Pale violet	Long	Pendant	Intermediate	Intermediate
RV100215	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100217	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100218	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100234	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100239	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100240	Upright	None	Very many	White	Round	Horizontal	Long	Large
RV100241	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100242	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100243	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100246	Upright	Many	Very many	White	Round	Semi pendant	Intermediate	Large
RV100248	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100249	Upright	None	Very many	White	Round	Pendant	Intermediate	Large
RV100250	Upright	Many	Very many	White	Round	Horizontal	Long	Large
RV100252	Upright	Many	Very many	White	Round	Semi erect	Long	Large
RV100259	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100260	Upright	None	Very many	White	Round	Pendant	Intermediate	Large
RV100261	Upright	Many	Very many	White	Round	Pendant	Short	Intermediate
RV100262	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100263	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100264	Upright	None	Very many	White	Round	Horizontal	Long	Large
RV100265	Upright	None	Very few	White	Round	Semi erect	Short	Small
RV100266	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100268	Upright	None	Very many	Light violet	Round	Pendant	Intermediate	Large
RV100270	Intermediate	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100271	Prostrate	None	Very few	White	Round	Pendant	Short	Small
RV100273	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100274	Intermediate	None	Very few	Greenish white	Round	Pendant	Short	Small
RV100300	Upright	None	Very few	White	Round	Pendant	Short	Small
RV100325	Upright	Many	Very many	White	Round	Pendant	Intermediate	Intermediate

Table 3.5: Morphological descriptors of 72 African eggplants grown in the greenhouse

AC. CODE	P.G.H	L.P	L.H	F.C	FR.SH	FR.P	F.L	F.B
RV100331	Intermediate	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100327	Upright	None	Very many	White	Round	Pendant	Intermediate	Large
RV100328	Upright	None	Very few	White	Round	Horizontal	Short	Small
RV100332	Upright	Many	Very many	Light v	Round	Semi erect	Long	Large
RV100333	Upright	None	Very many	White	Round	Pendant	Short	Intermediate
RV100334	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100335	Upright	None	Very few	White	Round	Pendant	Short	Small
RV100342	Upright	Many	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100343	Upright	None	Very few	White	Round	Pendant	Short	Small
RV100346	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100352	Upright	None	Very many	Pale violet	Round	Pendant	Intermediate	Large
RV100356	Upright	None	Very few	White	Round	Semi pendant	Short	Small
RV100359	Upright	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100360	Prostrate	None	Very few	White	Round	Pendant	Short	Small
RV100364	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100377	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100380	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100382	Upright	None	Very many	White	Round	Pendant	Short	Small
RV100386	Intermediate	None	Very many	White	Round	Semi pendant	Intermediate	Large
RV100431	Intermediate	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100432	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100438	Upright	None	Very many	White	Long	Horizontal	Long	Large
RV100438	Upright	Many	Very many	White	Long	Pendant	Long	Large
RV100445	Intermediate	Many	Very many	Bluish violet	Long	Pendant	Long	Large
RV100447	Upright	None	Very many	White	Round	Pendant	Intermediate	Intermediate
RV100449	Intermediate	Many	Very many	White	Round	Pendant	Intermediate	Large
RV100452	Upright	Many	Very few	White	Round	Pendant	Short	Small
RV100453	Upright	None	Very few	White	Round	Pendant	Intermediate	Intermediate
RV100455	Upright	Many	Very many	Pale violet	Long	Pendant	Intermediate	Intermediate
RV100456	Prostrate	None	Very many	White	Long	Pendant	Intermediate	Intermediate
RV100511	Upright	None	Very many	White	Long	Pendant	Intermediate	Intermediate

P.G.H-plant growth habit, L.P-Leaf prickles, L.H-Leaf hairs, F.C-Flower colour, FR.SH-Fruit shape, FR.P-Fruit position

F.L-Fruit length, F.B-fruit breadth

3.7.3 Leaf characteristics

In both field and greenhouse experiments, accessions with many leaf prickles comprised 31.9%, while those with no leaf prickles comprised 68.1% (Table 3.4, Table 3.5 and Figure 3.3). For example, accessions RV100194, RV100250, RV100332, RV100185 and RV100449 had many

leaf prickles while accessions RV100333, RV100245, RV100331, RV100333, RV100447 and RV100360 had no leaf prickles. Among the seventy two accessions, 70.8% had many leaf hairs while 29.2% had very few leaf hairs (Table 3.4, Table 3.5 and Figure 3.3). Accessions RV1001201, RV100161, RV100165, RV100169, RV100185, RV100250, RV100251 and RV100259 are examples of the accessions with many leaf hairs while RV100190, RV100199, RV100215, RV100234 and RV100239 are the examples of accessions that had few leaf hairs.

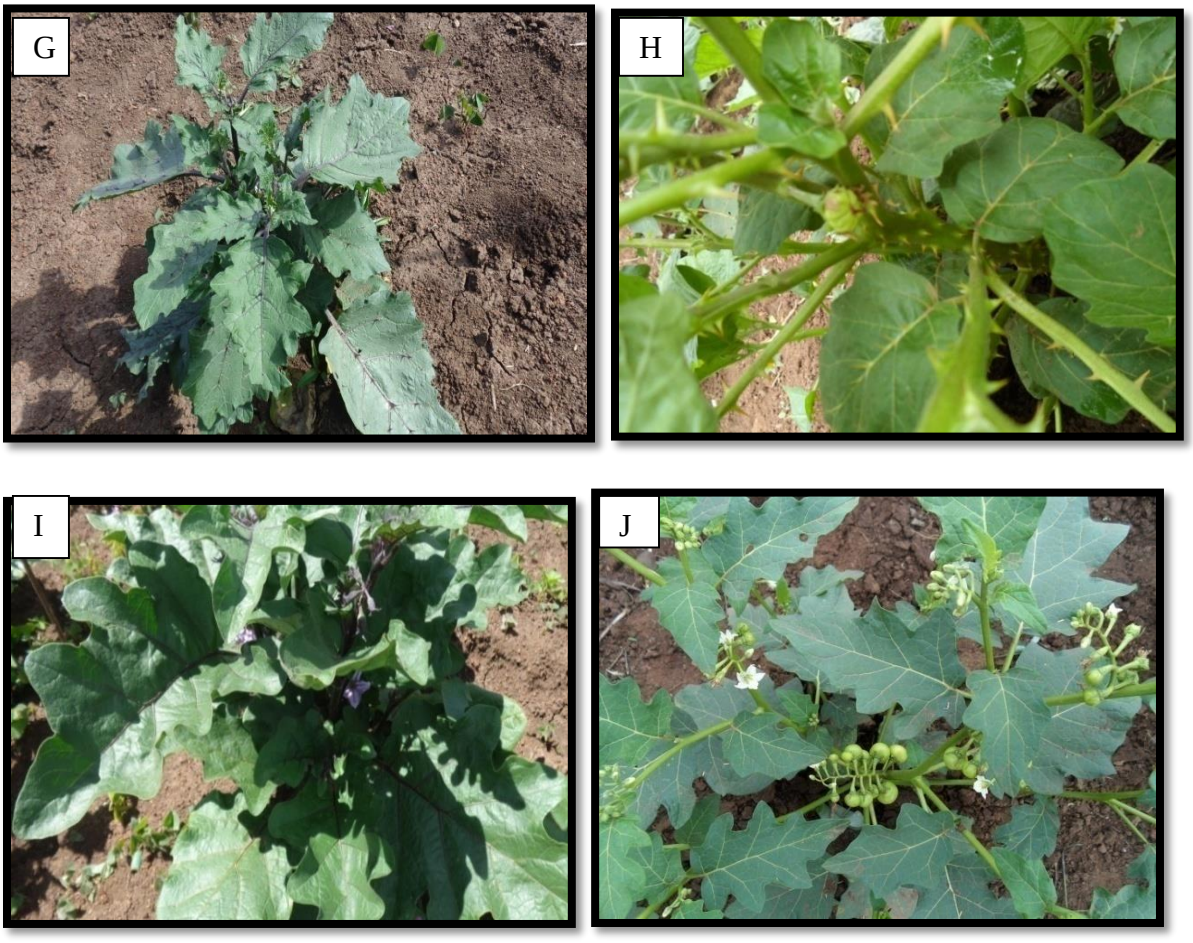


Figure 3.3: (G) Accession RV100194: purple stems, leaf prickles and leaf hairs; (H) Accession RV100250: Leaf hairs and leaf prickles; (I) Accession RV100455: Leaf hairs, Pale violet flowers, long and wide leaves; (J) Accession RV100453: Semi-erect fruit position, white flowers and medium sized leaves.

3.7.4 Fruit characteristics

The shapes of the fruits for the study accessions in both the field and greenhouse were round (81.9%) and long (18.1%). Fruit position, both in the field and greenhouse, were pendant (77.8%),

semi pendant (6.9%), horizontal (11.1%) and semi erect (4.2%) (Table 3.4, Table 3.5 and Figure 3.4). Fruit length and fruit breadth varied between field and the greenhouse. The proportions of fruit length in the field were intermediate (58.3%), short (27.8%) and long (13.9%) while in the greenhouse they were intermediate (46.6%), short (33.3%), long (11.1%), very long (4.2%) and very short (2.8%). The fruit breadths in the field were intermediate (47.2%), large (27.8%) to small (25%) while in the greenhouse they were large (44.4%), intermediate (43.1%), small (8.3%), very small (2.8%) and very large (1.4%) (Table 3.4, Table 3.5 and Figures 3.5–3.11).

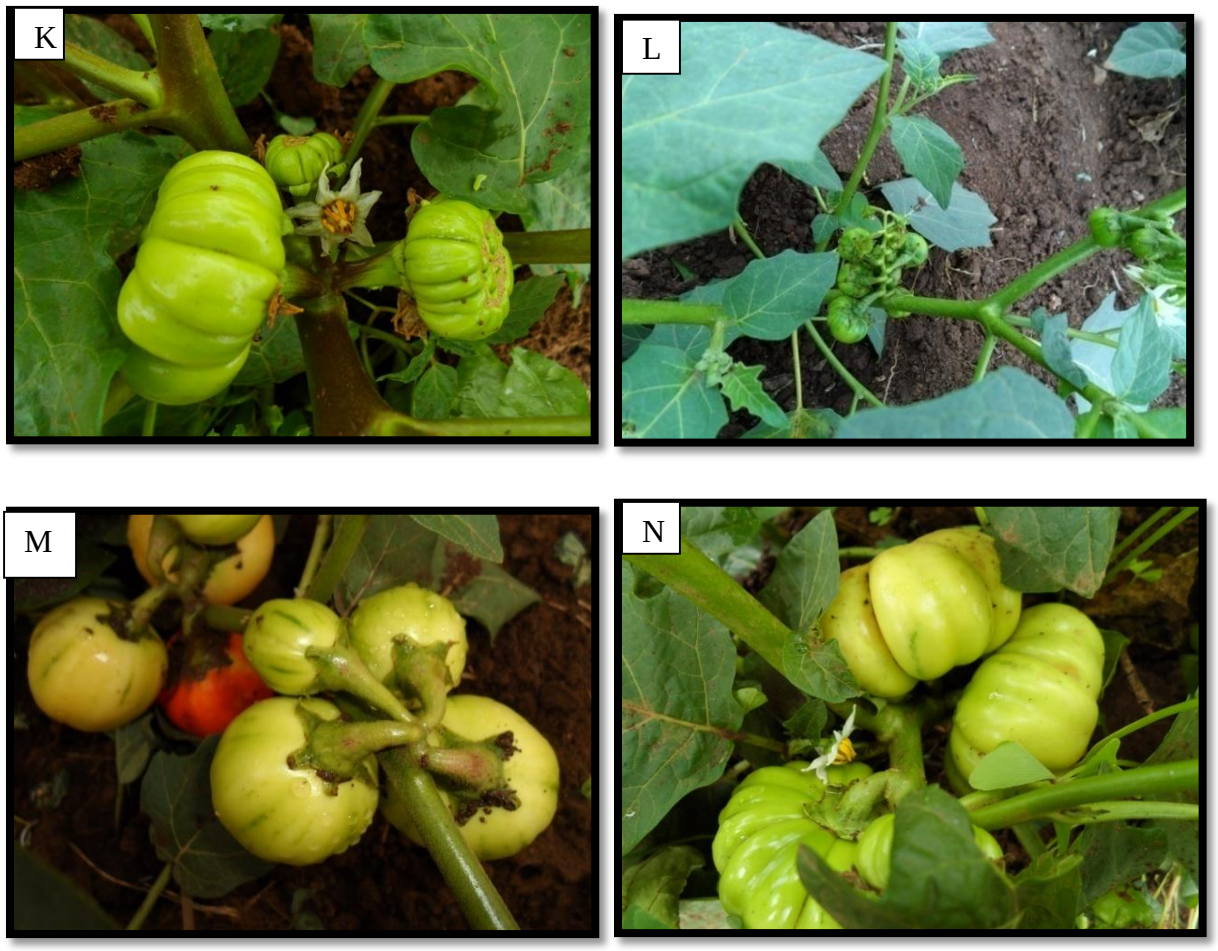


Figure 3.4:(K) Accession RV100273: erect fruit position; (L) Accession RV100274: Semi-pendant fruit position, long and wide leaves; (M) Accession RV1001201: pendant fruit position; (N) Accession RV100334: horizontal fruit position

Figure 3.5: Accessions RV100161 and RV100185 were round and have rough surfaces. Accessions RV100169 and RV100194 were round and large. Accession RV100190 were small sized, round and smooth surfaced. Accession RV100200 his round and yellow when ripe. Accession RV100217 his medium sized, round and smooth surfaced. Accession RV100218 his round and medium sized fruits.

Figure 3.6: Accessions RV100234, RV100240, RV100241, RV100242, RV100246, RV100247 and RV100250 were round, large with irregular surfaced. Accession RV100239 was long shaped and yellow in colour when ripe.

Figure 3.7: Accessions RV100259, RV100260, RV100261, RV100263, RV100264, RV100265, RV100270 and RV100271 were large, round with irregular surfaces.

Figure 3.8: Accession RV100300 was medium sized, egg like in shape and a smooth regular surface. Accessions RV100271, RV100273, RV100327, RV100332, RV100333, RV100334 and RV100335 were large, round with irregular surfaces.

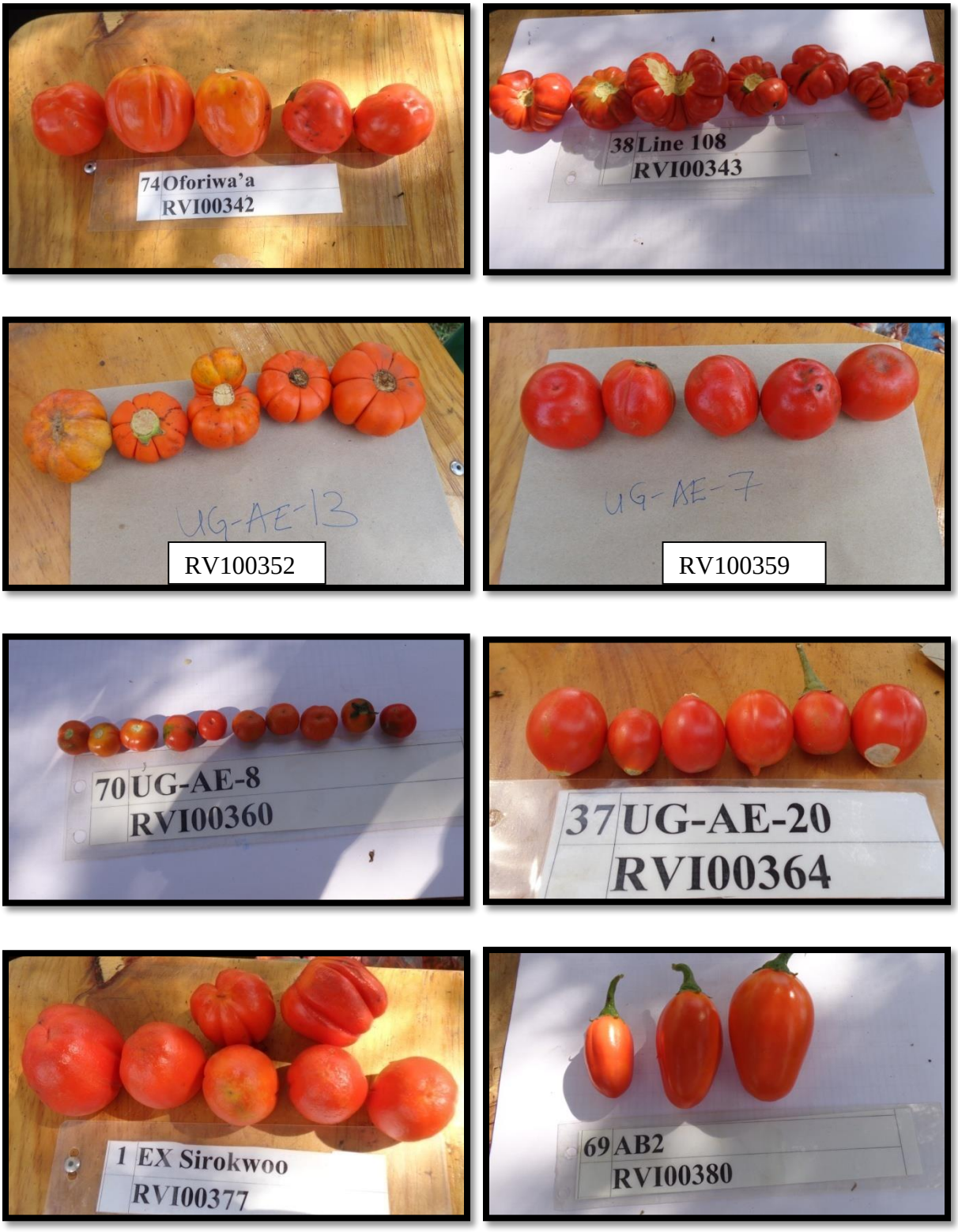


Figure 3.9: Accessions RV100342, RV100359 and RV100377 were medium sized, round with smooth surfaces. Accession RV100343 was large, round with irregular surface. Accession RV100352 had medium, round and smooth surface fruits. Accession RV100360 had small, round and smooth surface fruits. Accession RV100364 had medium, round with smooth surface. Accession RV100380 had medium, slightly long with a smooth surface.

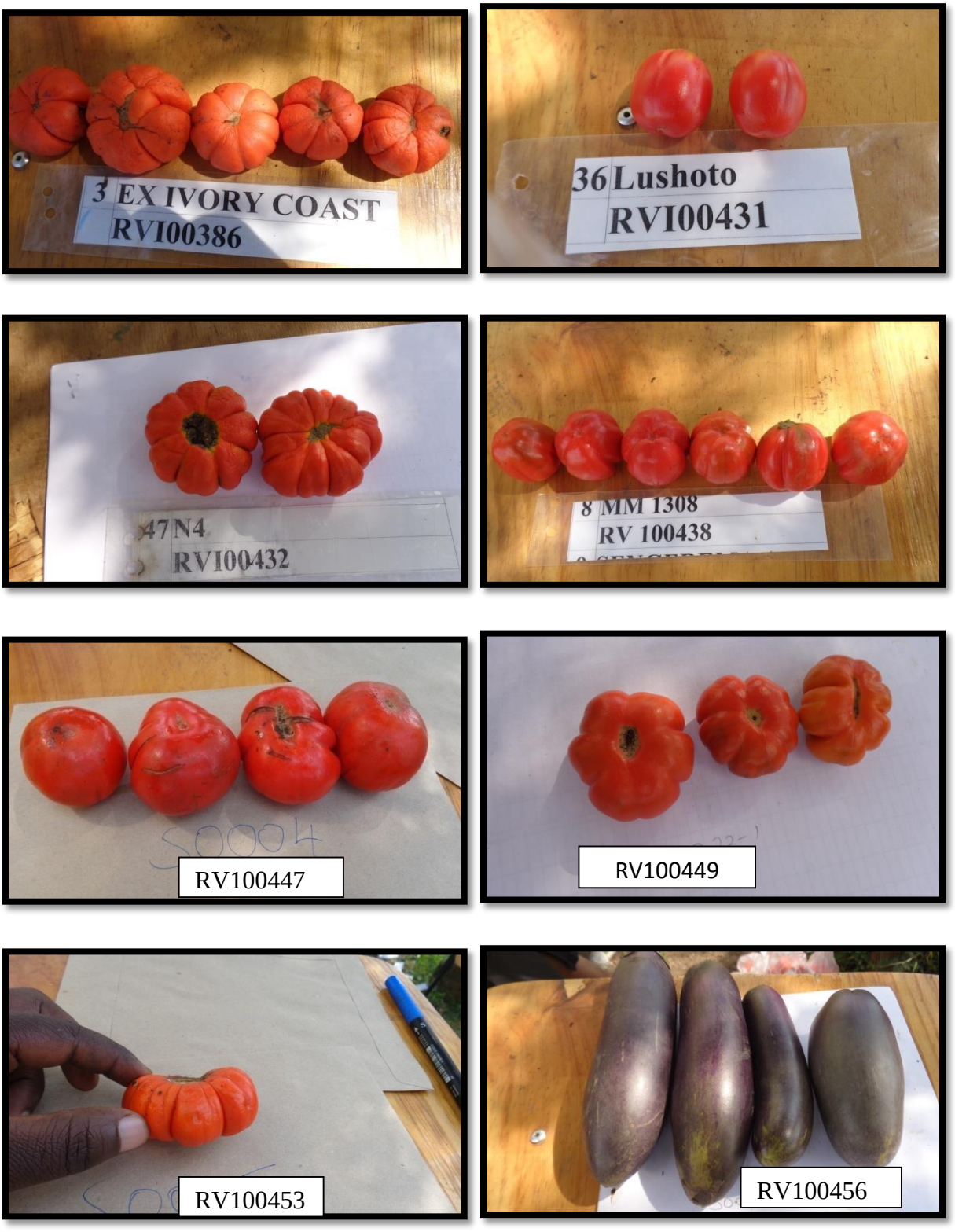


Figure 3.10: Accession RV100386 had medium, round with irregular surface. Accessions RV100431, RV100438 and RV100447 were medium sized, round and smooth surface. Accessions RV100432, RV100449 and RV100453 were large, round with irregular surfaces. Accession RV100456 had a long shape with a purple colour.

Figure 3.11: Accession RV100458 had medium, slightly long with smooth surface. Accessions RV100511 and RV1001201 had large, round with irregular surfaces. Accession GBK 050572 was long in shape and yellow in colour.

3.7.5 Diversity index for the qualitative characters

Estimates of Shannon-Weaver (H') for the qualitative characters evaluated in the studied accessions were high for both field and greenhouse experiments (Table 3.6). All traits showed high (H'>0.500) levels of polymorphism in both experiments. In the greenhouse and field experiments the indices ranged from 0.9298 (fruit shape) to 0.9941 (fruit position). Variation between the averages of the field and the greenhouse experiments were observed in fruit length and fruit breadth. The indices for fruit length and fruit breadth were 0.9848 and 0.9902, respectively, in the field experiment and 0.9795 and 0.9869, respectively, in the greenhouse experiment.

Table 3.6: **Standard Shannon Weaver diversity index (H') for qualitative characters in 72 African eggplant accessions grown in the field and in the glasshouse**

Qualitative trait	Shannon-Weaver index (H')	
	Field	Greenhouse
Growth habit	0.9935	0.9935
Leaf hairs	0.9523	0.9523
Leaf prickles	0.9866	0.9866
Flower colour	0.9898	0.9898
Fruit shape	0.9298	0.9298
Fruit position	0.9941	0.9941
Fruit length	0.9848	0.9795
Fruit breadth	0.9902	0.9869
Total diversity index	0.9955	0.9951

3.7.6 Genetic relationships based on principal coordinate analysis

The four main axes (axis 1, 2, 3 and 4) explained 49.5, 22.9, 9.02 and 6.2% of the total variation respectively for the accessions grown in the field giving a cumulative total variation of 88.15% (Table 3.7). Axes 1, 2, 3, 4, 5 and 6 contributed 16.66, 7.71, 3.04, 2.24, 2.02 and 0.98 of the eigenvalues respectively, for the field grown accessions (Table 3.7).

Table 3.7: **Eigenvalues and total variation of six principal components for 72 African eggplant accessions grown in the field and in the greenhouse**

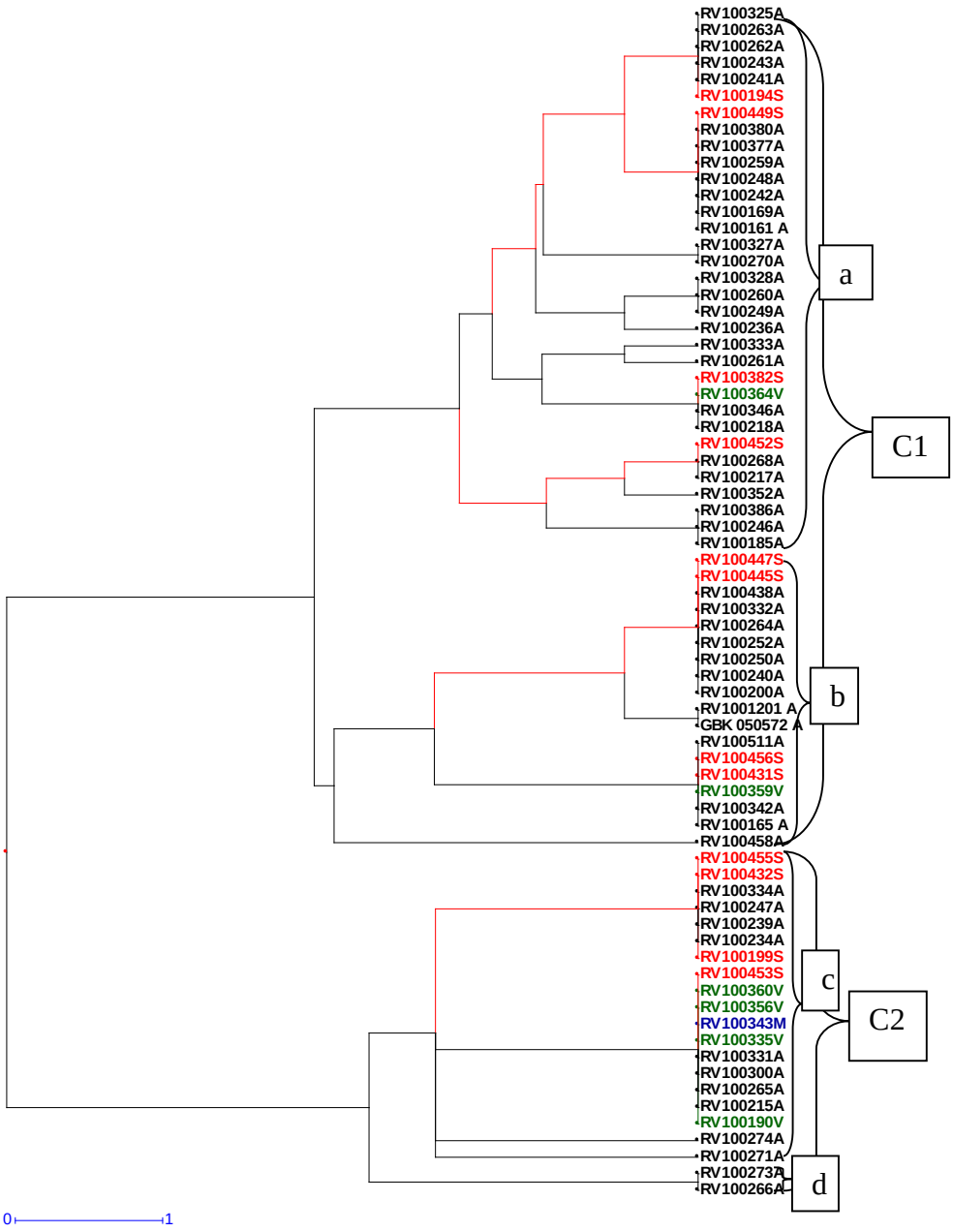
Axis	Eigenvalue		% of variance		Cumulative % of variance	
	Field	Greenhouse	Field	Greenhouse	Field	Greenhouse
1	16.66	16.68	49.53	46.23	49.53	46.23
2	7.71	7.68	22.93	21.3	72.46	67.53
3	3.04	4.18	9.02	11.58	81.48	79.11
4	2.24	2.87	6.67	7.97	88.15	87.08
5	2.02	2.31	5.99	6.39	94.14	93.47
6	0.98	1.02	2.91	2.82	97.05	96.29

According to the accessions grown in the greenhouse, the four main axes explained 46.23, 21.3, 11.58 and 7.97% of the total variations, respectively, giving a cumulative total of 87.08% of the variance (Table 3.7). The six axes (1, 2, 3, 4, 5 and 6) contributed 16.68, 7.68, 4.18, 2.87, 2.31 and 1.02 of the eingenvalues respectively, for greenhouse grown accessions as shown in (Table 3.7).

3.7.7 Genetic relationship based on cluster analysis

The phenogram was generated using eight morphological descriptors (growth habit, leaf prickles, leaf hairs, flower colour, fruit shape, fruit position, fruit breadth and fruit length) based on Euclidean Distance Coefficient and Unweighted Pair Group Method using Arithmetic averages (UPGMA) clustering method clearly showed the phenetic relationship among the accessions. Cluster analysis revealed two major clusters (Cluster I and II) for study accessions grown in the field (Figure 3.12). Cluster I had 51 accessions while cluster II had 21 accessions. Cluster I comprised 39 S. *aethiopicum,*10 *Solanum* species and 2 S. *anguivi* accessions while cluster II had 1 S. *macrocarpon,* 4 *Solanum* species, 4 S. *anguivi* and 12 S. *aethiopicum* accessions. Within species variation was observed for S. *aethiopicum,* S. *anguivi* and *Solanum* species accessions for example Figure 3.12 cluster I sub cluster ‘a’ shows a close relationship among S. *aethiopicum* accessions RV100325, RV100263 and RV100262, S. *anguivi* accession RV100364 and *Solanum* species accessions RV100194, RV100449 and RV100382. Sub cluster ‘a’ was made up of accessions with round fruit shape and pendant fruit position on the tree. Cluster I sub cluster ‘b’ was made of accessions sharing the character of very many leaf hairs on the lower surface of the leaf blade. Some accessions representing the bigger group in sub cluster ‘b’ included RV100438, RV100332 and RV100264 in S. *aethiopicum,* RV100447, RV100445 and RV100456 in S*olanum* species and RV100359 in S. *anguivi*. Cluster II comprised two sub clusters ‘c’ and‘d’. Sub cluster ‘c’ comprised accessions with the same flower colour (white). These accessions included

RV100247, RV100239 and RV100234 in S. *aethiopicum*, RV100455, RV100432 and RV100453 in S*olanum* species, RV100360, RV100356 and RV100335 in S. *anguivi* and the only S. *macrocarpon* accession RV100343. Sub cluster'd' was made up of accessions RV100273 and RV100266 within S. *aethiopicum* species. These accessions had no leaf prickles and had the same fruit length. In sub-cluster 'a', of the 32 accessions originating from one node, accessions RV100325 and RV100185 had a longer genetic distance from each other even though they were from the same species S. *aethiopicum*. Variation was also seen in S. *anguivi* and *Solanum* species because accessions of the same species appeared in different clusters as shown in Figure 3.12. In S. *anguivi* accession RV100364 was varied genetically from RV100190 because they were found in different clusters yet they belong to the same species. Accessions RV100194 and RV100453 belonging to *Solanum* species were found on different clusters yet they belong to the same species.



C-cluster

Figure 3.12: Unweighted pair-group method using arithmetic averages cluster analysis phenogram showing the relationships among the 72 African eggplant accessions grown in the field. The letters at the end of each accession represents the species; A-*aethiopicum*, V-*anguivi*, S-*Solanum* species and M-*macrocarpon*.

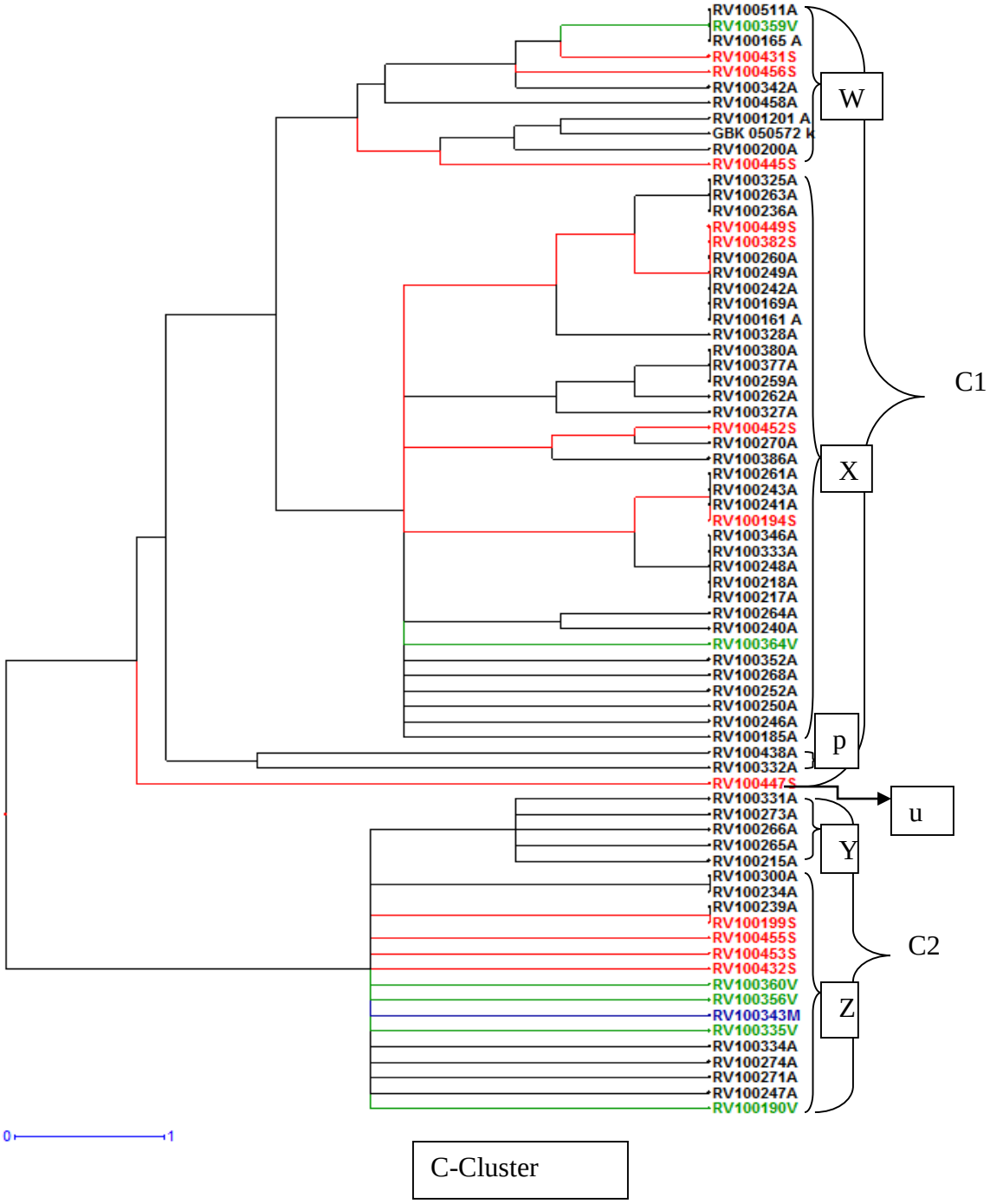


Figure 3.13: Unweighted pair-group method using arithmetic averages cluster analysis phenogram showing the relationships among the 72 African eggplant accessions grown in the greenhouse. The letters at the end of each accession represents the species; A-*aethiopicum*, V-*anguivi*, S-*Solanum* species and M-*macrocarpon*.

For the greenhouse grown accessions, cluster phenogram exposed two major clusters (Cluster I and II) (Figure 3.13). Cluster I was made up of four sub clusters (p, u, w and x) according to figure 3.13. While cluster II comprised two sub clusters (y and z). In cluster I sub cluster 'p' accessions RV100438 and RV100332, both of which belong to S. *aethiopicum* species, were grouped together due to their upright growth habit. Sub cluster 'u' had a single accession RV100447 belonging to *Solanum* species and was uniquely known for its small sized fruits. Sub cluster 'w' was made up of accessions with pendant fruit positioning on the plant, including accessions in S. *aethiopicum* species (RV100511, RV100342 and RV100458), *Solanum* species (RV100431, RV100456 and RV100445) and 1 S. *anguivi* accession (RV100359). Finally the biggest sub cluster in cluster I was 'x'. This sub cluster was made of accessions which had very many leaf hairs on the lower surface of the leaf blade. The accessions in sub cluster 'x' included accessions in S. *aethiopicum* (RV100325, RV100328 and RV100333), *Solanum* species (RV100449, RV100452 and RV100382) and S. *anguivi* (RV100364). In cluster II sub cluster 'y' was made up of accessions with the same fruit shape 'round' from S. *aethiopicum* species (RV100331, RV100273, RV100266, RV100265 and RV100215). Sub cluster 'z' was made of a mixture of accessions with the same flower colour 'white'. They included accessions in S. *aethiopicum* (RV100300, RV100234, RV100239, RV100334, RV100274, RV100271 and RV100247), *Solanum* species (RV100199, RV100455, RV100453 and RV100432), S. *anguivi* (RV100360, RV100356, RV100335 and RV100190) and S. *macrocarpon* (RV100343). Variation within species was also observed clearly in S. *anguivi* whereby RV100359 was found in cluster I in sub cluster 'w' while RV100190 was found in cluster II at sub cluster 'z' far away from each other yet they belonged to the same species.

3.7.8 Principal component analysis

The percentage variation explained by the first six principal components (PC) and the vector loadings for each character and PC are presented in Tables 3.7 and 3.8. The first six PCs explained 97.05% of the variation among the 72 field grown accessions and 96.29% among the greenhouse grown accessions.

Table 3.8: **Eigenvalues[a], eigenvectors[b] and percentage of variation explained by the first six principal components for 72 African eggplant accessions grown in the field**

Qualitative character	Principal component					
	1	2	3	4	5	6
Variation explained (%)	49.53	22.93	9.02	6.67	5.99	2.91
Eigenvalue	16.66	7.71	3.04	2.24	2.02	0.98
Fruit breadth	0.057	0.071	0.252	0.128	**0.785**	0.24
Flower colour	0.088	0.035	0.003	-0.315	-0.086	**0.905**
Fruit length	0.038	0.075	0.283	-0.091	**0.468**	-0.217
Fruit position	0.051	-0.151	**0.828**	0.385	-0.357	0.096
Fruit shape	0.137	-0.046	0.36	**-0.84**	-0.075	-0.248
Leaf hairs	**0.812**	**-0.55**	-0.16	0.086	0.061	-0.031
Leaf prickles	**0.554**	**0.812**	0.023	0.09	-0.136	-0.056
Plant growth habit	-0.003	-0.036	0.122	-0.084	0.043	0.036

[a]Eigenvalues indicate the amount of variance explained by each principal component

[b]Eigenvectors are the weights in a linear transformation when computing principal components

Values in bold indicate the most relevant descriptors that contributed most to specific components

Leaf hairs and leaf prickles were the main traits that contributed positively to PC1 for the accessions grown in the field (Table 3.8). Leaf prickle was the most important character that contributed to the second principal component in field grown accessions while fruit position, fruit length and flower colour were the most important characters in the third, fifth and sixth principal components respectively. It was also observed that fruit shape had negative loading to fourth principal component at -0.84.

Table 3.9: Eigenvalues[a], eigenvectors[b] and percentage of variation explained by the first six principal components for 72 African eggplant accessions grown in the greenhouse

Qualitative character	Principal component					
	1	2	3	4	5	6
Variation explained (%)	46.23	21.3	11.58	7.97	6.39	2.82
Eigenvalue	16.676	7.683	4.178	2.874	2.305	1.018
Fruit breadth	0.052	0.058	0.56	-0.316	0.397	0.407
Flower colour	0.088	-0.04	0.002	0.042	-0.3	**0.844**
Fruit length	0.063	0.074	**0.748**	-0.05	-0.071	-0.319
Fruit position	0.051	0.159	0.098	**0.866**	0.444	0.099
Fruit shape	0.14	0.057	0.278	0.338	**-0.733**	0.099
Leaf hairs	**0.815**	**0.529**	-0.173	-0.143	0.045	-0.053
Leaf prickles	**0.548**	**-0.824**	0.038	0.074	0.098	-0.056
Plant growth habit	-0.002	0.042	0.092	0.082	-0.044	0.053

[a]Eigenvalues indicate the amount of variance explained by each principal component

[b]Eigenvectors are the weights in a linear transformation when computing principal components

Values in bold indicate the most relevant descriptors that contributed most to specific components

For the greenhouse grown accessions, leaf hairs, fruit length, fruit position and flower colour contributed positively to principal component one, three, four and six respectively (Table 3.9). Leaf prickles was the most important character that contributed negatively to the second principal component while fruit shape, fruit length, flower colour and plant growth habit had negative loadings to the fifth principal component of the greenhouse grown accessions. It was evident that characters that made significant contributions to a particular principal component were important contributors to other principal components.

3.8 Quantitative characters

3.8.1 Plant height

Significant ($P<0.05$) differences in plant height were observed among the study accessions in the field and greenhouse (Table 3.10 and Table 3.11). In the field, plant height varied from 12.7 cm (accession RV100271) to 81.8 cm (accessionRV100458). Similarly, in the greenhouse plant height

varied from 9.5 cm (accession RV100271) to 79 cm (accession RV100458). On average greenhouse grown accessions had similar height with field grown accessions. The mean of the height of accessions grown in the greenhouse and field were 37.54 cm and 37.43 cm respectively. Among the tallest 6 accessions there were 3 S. *aethiopicum* accessions (RV100458, RV100300 and RV100169), 2 S. *anguivi* accessions (RV100356 and RV100364) and 1 S*olanum* species accession (RV100456) while among the shortest 6 accessions were 5 S. *aethiopicum* accessions (RV100260, RV100327, RV100239, RV100333 and RV100271) and 1 *Solanum* species accession (RV100199). *Solanum aethiopicum* species accessions were the most diverse; they provided the tallest and the shortest accession both in the field and greenhouse.

3.8.2 Leaf blade length

A significant ($P<0.05$) variation in the leaf blade length among the field and greenhouse grown accessions was observed. The leaf blade length measured across the 72 eggplant accessions in the field ranged from 7.1 cm (accession RV100261 and RV100333) to 29.4 cm (accession RV100364) with a mean of 15.95 cm (Table 3.10). In the greenhouse, leaf blade length varied from 6.7 cm (accession RV100261) to 28.4 cm (accession RV100352) with a mean of 16.18 cm (Table 3.11).

3.8.3 Leaf blade width

Significant ($P<0.05$) variations in the leaf blade width among the field and greenhouse grown accessions were observed (Table 3.11). In the field grown accessions leaf blade width varied from 2.5 cm (accession RV100261) to 20.1 cm (accession RV100332) with a mean of 8.56 cm (Table 3.10). Leaf blade widths ranged from 3.1 cm (accession RV100261) to 22.8 cm (accession RV100332) with a mean of 10.01 cm, in the greenhouse (Table 3.11).

Table 3.10: Quantitative trait means of 72 African eggplant accessions grown in the field

S/no	Accessions	P H	LBL	LBW	FL	FB	FW(g)	NOF	SPAD	DTF
1	GBK 050572	38.5	9.0	8.3	12.9	5.8	54.3	18.0	62.0	56.7
2	RV1001201	45.5	15.2	9.7	14.3	6.0	81.2	6.2	49.2	54.0
3	RV100161	23.4	19.2	9.3	7.2	6.2	32.5	66.1	52.0	51.3
4	RV100165	27.3	14.6	9.2	7.3	4.7	32.5	20.6	59.5	54.7
5	RV100169	64.1	15.2	11.4	7.2	5.1	25.9	42.7	62.2	55.3
6	RV100185	45.7	16.3	6.0	4.4	3.4	10.0	40.0	52.6	54.7
7	RV100190	27.9	17.1	6.8	4.2	3.0	4.4	132.9	63.3	55.0
8	RV100194	17.7	16.0	8.2	5.6	4.6	15.1	127.5	57.1	52.7
9	RV100199	13.9	13.4	5.8	5.4	5.5	48.4	11.0	67.7	54.7
10	RV100200	60.1	20.7	9.8	14.6	9.0	152.8	18.1	57.7	56.3
11	RV100215	22.7	13.8	7.9	7.4	6.0	47.8	9.8	58.6	56.7
12	RV100217	41.8	13.6	4.6	4.8	3.3	8.6	95.8	60.6	54.3
13	RV100218	62.1	15.2	4.8	4.0	3.3	3.2	42.8	55.5	56.0
14	RV100234	23.6	18.6	18.3	11.0	5.6	35.0	11.2	62.2	50.7
15	RV100236	15.2	18.2	16.6	9.1	5.8	74.3	5.8	58.1	53.3
16	RV100239	45.9	21.1	8.1	5.4	5.0	28.7	6.9	59.0	60.0
17	RV100240	38.1	9.2	5.8	4.5	3.6	13.5	8.4	57.9	55.3
18	RV100241	50.2	15.8	8.2	5.6	3.9	14.3	6.4	50.0	55.3
19	RV100242	36.9	13.6	8.5	7.8	6.5	28.9	29.5	51.0	53.7
20	RV100243	54.9	14.6	9.4	4.8	4.5	18.1	3.4	31.6	55.7
21	RV100246	41.6	15.2	8.1	6.6	6.6	26.1	66.9	57.7	54.7
22	RV100247	31.5	15.2	7.3	7.2	5.6	31.4	30.8	46.8	53.3
23	RV100248	27.8	12.7	6.5	3.9	4.0	12.2	8.2	61.4	56.7
24	RV100249	45.0	19.2	16.2	6.0	5.4	26.2	29.6	55.9	60.7
25	RV100250	18.1	16.2	9.8	6.8	5.6	20.4	16.3	52.2	55.7
26	RV100252	42.8	14.0	7.0	6.0	5.2	20.8	66.0	64.2	51.7
27	RV100259	12.8	14.0	7.9	7.6	5.0	64.0	10.8	60.9	56.7
28	RV100260	16.9	14.6	8.6	7.7	6.5	22.2	15.5	51.7	49.0
29	RV100261	29.1	7.8	2.8	4.8	4.2	14.7	8.3	55.6	52.7
30	RV100262	27.7	15.2	7.8	6.0	4.6	12.2	12.7	55.2	55.0
31	RV100263	45.8	17.8	9.1	6.4	5.9	16.7	24.5	65.9	51.0
32	RV100264	13.8	17.0	7.2	7.2	4.9	18.2	12.3	60.6	58.3
33	RV100265	25.9	17.0	8.1	7.7	6.1	36.6	38.5	55.3	53.7
34	RV100266	31.0	13.6	9.2	5.7	5.8	24.3	77.7	64.2	49.7
35	RV100268	30.9	13.5	9.2	7.1	6.8	62.4	12.5	52.3	48.3
36	RV100270	28.2	19.0	9.1	7.3	5.4	41.0	33.0	58.9	54.3
37	RV100271	12.7	7.8	3.9	6.9	5.2	22.7	21.8	59.3	56.7
38	RV100273	25.8	16.9	7.5	6.7	5.9	35.0	4.7	55.6	55.0
39	RV100274	49.7	14.3	8.5	9.5	6.8	19.2	18.5	48.6	49.7
40	RV100300	81.0	17.6	11.4	10.0	7.8	68.3	14.0	48.6	52.3
41	RV100325	44.6	14.6	7.3	6.6	6.1	32.8	19.3	62.9	58.7
42	RV100327	15.8	12.1	6.4	5.7	4.6	27.3	5.0	58.5	56.0
43	RV100328	36.7	19.2	10.3	10.1	7.9	63.4	9.0	57.0	54.3
44	RV100331	17.8	14.1	7.0	10.6	7.9	82.6	5.8	56.6	57.7
45	RV100332	48.7	23.4	18.0	5.7	3.8	24.0	19.2	64.2	54.7
46	RV100333	16.8	7.8	3.6	3.6	4.4	22.7	9.3	59.9	55.7
47	RV100334	35.8	13.4	7.2	8.4	4.3	21.8	9.7	54.2	55.0

Table 3.10: Quantitative trait means of 72 African eggplant accessions grown in the field

48	RV100335	55.7	9.6	5.0	4.7	2.6	2.5	211.7	51.2	52.0
49	RV100342	55.9	22.0	8.3	9.4	5.5	35.0	42.8	55.6	55.3
50	RV100343	39.8	19.0	4.5	2.9	2.3	2.3	140.8	61.0	54.0
51	RV100346	19.8	16.0	6.1	4.3	3.9	10.9	37.0	60.1	52.0
52	RV100352	17.3	28.0	12.7	4.6	4.5	15.5	19.5	55.5	51.7
53	RV100356	69.8	16.5	6.1	4.7	2.8	2.8	24.2	67.1	55.3
54	RV100359	65.8	15.4	7.9	6.0	3.4	24.0	53.5	54.5	53.0
55	RV100360	21.7	16.1	8.5	2.8	2.3	1.7	203.7	53.1	54.7
56	RV100364	67.0	28.1	12.5	4.2	3.0	4.2	13.3	63.2	54.0
57	RV100377	62.3	18.9	12.1	8.4	4.7	8.0	23.0	55.2	55.3
58	RV100380	22.0	13.0	11.2	9.6	4.8	26.2	22.7	54.7	52.3
59	RV100382	42.7	21.1	9.4	7.6	5.9	25.0	8.5	51.5	54.0
60	RV100386	26.8	11.3	5.8	8.1	6.4	36.6	15.5	53.3	48.3
61	RV100431	54.8	21.6	7.9	7.8	4.3	30.7	33.8	49.3	55.7
62	RV100432	13.8	10.0	5.8	5.4	4.4	20.8	12.8	68.6	57.0
63	RV100438	45.1	18.8	9.5	5.1	2.8	6.1	257.7	52.5	55.3
64	RV100445	44.2	13.2	6.7	14.6	5.6	88.1	20.0	54.4	56.7
65	RV100447	21.2	15.4	9.6	5.4	3.0	24.9	24.0	55.8	56.0
66	RV100449	27.6	16.6	5.7	9.2	5.8	52.2	20.5	37.7	58.0
67	RV100452	44.9	20.8	8.6	8.2	7.9	82.0	4.8	56.1	51.7
68	RV100453	44.8	13.2	4.8	3.5	2.7	3.3	372.2	60.9	56.7
69	RV100455	46.7	20.6	11.4	12.9	4.8	37.8	57.8	53.0	54.3
70	RV100456	68.8	11.8	8.1	9.2	4.6	20.8	102.7	62.2	52.3
71	RV100458	81.8	21.1	11.4	10.7	3.6	20.5	65.0	48.4	53.0
72	RV100511	25.8	15.7	14.8	7.3	3.7	13.3	86.5	58.9	55.3
	Mean	**37.4**	**16.0**	**8.6**	**7.1**	**5.0**	**30.5**	**44.1**	**56.5**	**54.4**
	Fpr	**<.001**	**<.001**	**<.001**	**0.02**	**0.991**	**0.1**	**0.57**	**<.001**	**<.001**
	Lsd p=0.05	**0.83****	**0.86****	**1.18****	**1.9***	**1.02ns**	**3.16ns**	**8.75ns**	**4.71****	**4.36****
	Cv (%)	**1.4**	**3.4**	**8.6**	**10.4**	**12.8**	**6.5**	**12.3**	**5.2**	**5**

Fpr=F probability, LSD=Least significant difference, PH=Plant growth habit (cm),LBL=Leaf blade length (cm), LBW=Leaf blade width (cm), FL=Fruit length (cm), FB-Fruit breadth (cm), FW=Fruit weight (g), NOF=Number of fruits per plant, SPAD=Chlorophyll content, DTF=Days to 50% flowering.

Table 3.11: Quantitative trait means of 72 African eggplant accessions grown in the greenhouse

S/no	Accessions	P H	LBL	LBW	FL	FB	FW(g)	N O F	SPAD	DTF
1	GBK 050572	43.4	9.3	9.1	13.7	5.1	49.5	20.0	67.5	55.0
2	RV1001201	49.4	16.6	10.9	13.9	6.1	79.7	6.7	46.6	53.0
3	RV100161	27.9	18.5	9.7	8.5	4.7	38.5	55.7	56.7	53.7
4	RV100165	28.3	15.3	8.5	8.1	4.5	29.0	20.6	62.2	53.0
5	RV100169	66.7	14.6	10.4	6.7	4.7	38.1	37.3	58.9	53.7
6	RV100185	47.6	16.9	6.8	6.2	2.6	7.2	37.0	57.7	53.0
7	RV100190	26.7	17.3	9.2	8.4	4.7	6.3	131.7	65.1	49.0
8	RV100194	24.5	15.2	9.9	5.2	4.1	12.3	136.3	63.3	53.7
9	RV100199	13.4	12.6	7.3	5.4	3.6	53.2	8.7	72.1	51.3
10	RV100200	58.8	21.6	11.4	13.5	7.7	140.2	20.7	62.5	53.0
11	RV100215	23.1	14.9	7.8	8.5	4.6	42.7	11.0	61.2	52.3
12	RV100217	49.3	13.5	4.9	3.1	2.8	5.4	92.3	53.8	52.3
13	RV100218	58.0	14.6	7.4	3.1	2.0	2.6	39.0	63.1	52.7
14	RV100234	17.9	17.5	17.1	9.1	4.6	33.6	6.7	63.6	50.3
15	RV100236	12.8	17.4	16.3	7.8	5.0	73.3	4.0	61.3	50.7
16	RV100239	42.6	20.7	9.5	5.5	4.8	43.4	9.7	56.3	53.3
17	RV100240	36.6	10.4	6.7	4.3	3.3	19.2	8.7	61.9	54.7
18	RV100241	46.2	15.5	8.3	7.2	4.2	18.2	11.7	55.9	55.7
19	RV100242	32.4	13.6	9.2	6.6	4.9	27.9	29.0	58.1	55.0
20	RV100243	56.4	15.5	10.5	8.0	4.4	18.4	5.0	40.2	51.7
21	RV100246	43.7	14.6	9.3	6.8	5.1	30.0	73.0	60.5	55.7
22	RV100247	29.1	14.5	7.5	7.7	4.6	28.7	26.7	52.4	52.3
23	RV100248	25.7	112.9	8.3	6.3	3.4	15.8	10.0	60.6	55.3
24	RV100249	44.0	19.2	15.2	6.3	6.0	30.9	26.3	61.4	54.0
25	RV100250	17.3	16.1	10.9	7.2	4.3	17.0	19.0	60.9	52.7
26	RV100252	42.4	14.6	9.4	6.6	3.6	18.9	61.7	65.7	51.7
27	RV100259	16.4	14.4	9.4	7.9	4.0	67.1	10.0	64.2	53.3
28	RV100260	15.2	14.4	9.6	8.3	6.4	18.4	17.7	55.7	51.3
29	RV100261	33.0	7.5	3.5	4.6	3.9	15.4	8.0	58.1	50.3
30	RV100262	24.7	14.5	8.2	7.1	4.6	7.7	17.3	55.4	53.0
31	RV100263	45.8	17.3	11.5	8.4	4.9	19.6	23.3	61.2	52.7
32	RV100264	19.4	16.5	9.4	6.5	4.0	20.8	11.0	62.8	53.7
33	RV100265	24.8	16.6	13.3	4.3	2.8	32.8	33.7	57.4	49.3
34	RV100266	31.6	14.0	8.9	5.0	3.9	21.3	73.0	55.3	49.7
35	RV100268	29.8	13.4	9.0	6.7	5.3	68.7	9.0	57.1	52.7
36	RV100270	26.2	18.4	9.8	6.6	4.3	39.9	33.3	65.3	49.7
37	RV100271	9.5	7.6	7.5	6.6	4.7	24.3	16.7	53.7	54.3
38	RV100273	24.4	17.2	9.6	7.4	4.8	40.6	9.0	61.2	53.3
39	RV100274	49.7	14.9	8.9	8.2	7.0	17.0	12.7	52.5	49.7
40	RV100300	72.6	21.2	14.4	9.7	7.7	59.0	14.3	57.0	50.3
41	RV100325	49.5	15.0	8.4	7.3	4.6	27.3	16.3	67.4	53.7
42	RV100327	14.9	12.5	7.6	5.4	4.4	30.2	9.7	56.8	54.3
43	RV100328	42.6	20.0	14.8	11.0	7.6	73.7	7.0	62.0	52.0
44	RV100331	17.3	14.2	9.3	10.0	7.3	75.4	10.0	63.9	51.3
45	RV100332	48.0	23.7	21.6	4.5	3.2	24.4	29.3	69.2	52.7
46	RV100333	12.8	8.7	5.5	4.7	3.7	25.1	8.3	66.2	54.7

Table 3.11: Quantitative trait means of 72 African eggplant accessions grown in the greenhouse

47	RV100334	35.4	12.7	8.8	9.0	4.8	23.1	9.3	56.8	51.7
48	RV100335	56.5	11.0	7.1	5.0	2.7	3.6	189.0	57.9	54.0
49	RV100342	52.5	20.8	9.2	7.5	3.8	33.4	49.3	56.7	52.7
50	RV100343	45.0	19.4	6.4	2.1	1.7	1.3	149.3	63.6	50.7
51	RV100346	19.3	17.6	6.5	4.3	2.8	7.3	34.0	61.5	54.0
52	RV100352	15.8	27.3	14.4	4.1	3.9	18.4	15.3	52.0	54.0
53	RV100356	64.2	17.0	9.0	4.4	2.1	2.4	30.3	64.8	52.0
54	RV100359	61.2	15.5	10.4	3.8	2.5	20.7	50.3	61.3	52.3
55	RV100360	20.3	15.6	11.4	2.0	1.7	1.3	205.0	60.3	53.0
56	RV100364	64.0	25.4	14.2	5.0	2.5	7.6	14.7	68.8	52.3
57	RV100377	60.3	18.4	11.3	7.6	4.7	10.0	20.0	59.0	50.3
58	RV100380	29.2	13.5	13.6	8.4	4.5	22.2	24.7	63.0	52.3
59	RV100382	41.5	17.4	11.4	3.3	2.4	21.7	14.0	58.7	52.0
60	RV100386	30.6	16.1	9.6	7.4	5.8	37.8	15.0	64.5	52.0
61	RV100431	51.4	22.4	8.7	8.8	3.3	33.4	30.0	48.4	55.3
62	RV100432	15.9	14.6	8.1	5.4	3.3	18.2	9.3	66.6	56.0
63	RV100438	45.0	19.8	11.4	5.7	2.6	7.7	222.7	59.4	55.0
64	RV100445	47.0	13.5	8.4	15.4	5.0	82.3	23.3	57.3	53.0
65	RV100447	20.8	15.6	7.6	4.7	2.6	31.9	31.0	61.7	53.3
66	RV100449	32.2	16.7	8.3	9.8	4.7	54.4	23.7	45.6	53.0
67	RV100452	46.5	21.9	10.4	8.3	6.3	73.5	7.3	57.5	51.3
68	RV100453	53.2	14.6	9.2	4.4	3.5	2.5	354.7	63.4	53.0
69	RV100455	48.3	19.6	13.7	8.3	4.5	33.1	55.7	60.2	51.7
70	RV100456	65.5	14.6	10.6	9.6	4.1	20.8	118.3	66.4	52.0
71	RV100458	79.0	21.9	14.3	9.5	3.4	28.1	72.0	51.9	52.0
72	RV100511	29.4	16.6	15.4	6.7	2.9	10.0	82.7	57.3	53.7
	Mean	**37.5**	**16.2**	**10.0**	**7.0**	**4.3**	**30.5**	**43.5**	**59.7**	**52.7**
	F pr	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**0.05**
	lsd (p=0.05)	**4.18****	**1.36****	**0.81****	**1.06****	**0.83****	**3.69****	**4.96****	**5.02****	**3.82***
	Cv (%)	**6.9**	**5.2**	**5.0**	**9.4**	**12.2**	**7.5**	**7.1**	**5.2**	**4.5**

PH=Plant growth habit (cm), LBL=Leaf blade, length (cm), LBW=Leaf blade width (cm), FL=Fruit length (cm), FB= Fruit breadth (cm), FW=Fruit weight (g), NOF=Number of fruits per plant, SPAD= Chlorophyll greenness index, DTF=Days to 50% flowering, Fpr=F probability, LSD=Least significant difference.

**-Highly significant, *-significant, ns-not significant.

3.8.4 Fruit length

Significant differences were observed among the study accessions in the field and greenhouse for fruit length. In the field study, fruit length ranged from 1.7 cm (accession RV100343) to 15.9 cm (accession RV100445) with a mean of 7.12 cm (Table 3.10). In the greenhouse grown accessions fruit length ranged from 1.4 cm (accession RV100343) to 15.9 cm (accession RV100445), with a mean of 7.007 cm (Table 3.11).

3.8.5 Fruit breadth

Fruit breadth showed no significant differences among the field grown accessions. Fruit breadth among the accessions ranged from 1.5 cm (accession RV100343) to 9.8 cm (accession RV100200) with a mean of 5.0 cm (Table 3.10). In the greenhouse grown accessions, significant variations were recorded with fruit breadth ranging from 1.3 cm (accession RV100343) to 8.4 cm (accession RV100200) respectively with a mean of 4.3 cm, out of 72 accessions studied 35 of them had fruit breadths longer than 4.3 cm (Table 3.11).

3.8.6 Fruit weight

In the field experiments, there were no significant differences among the accessions for fruit weight (Table 10). Fruit weight ranged from 1.3 g (accession RV100360) to 156.7 g (accession RV100200) with a mean of 30.48 g. Accessions with more than average fruit weight included RV1001201 (81.2 g), RV100331 (82.6 g), RV100452 (82.0 g) and RV100236 (74.3 g) while a few with less than average fruit weight included RV100356 (2.8 g), RV100343 (2.3 g), RV100335 (2.5 g), RV100218 (3.2 g) and RV100190 (4.4 g) (Table 3.10). In the greenhouse experiments, there were highly significant ($P<0.01$) differences among the accessions in fruit weight (Table 11). Fruit weight ranged from 0.9 g (accession RV100360) to 143.5 g (accession RV100200), with a mean of 30.49 g. Twenty six of the 72 accessions had fruit weight of above 30.49 g. Accessions with more than average fruit weight included RV100445 (82.3 g), RV1001201 (79.7 g), RV100328 (73.7 g) and RV100452 (73.5 g) while a few with less than average fruit weight included RV100360 (1.3 g), RV100343 (1.3 g), RV100453 (2.5 g), RV100218 (2.6 g) and RV100217 (5.4 g) (Table 3.11).

Table 3.12: **Quantitative trait measurements of 72 field grown African eggplant accessions with their minimum and maximum values**

VARIATE	MIN	MEAN	MAX	SED	P value
Days to 50% flowering	45.0	54.5	63.0	2.2	<.001**
SPAD value	27.9	56.5	72.7	1.9	<.001**
Plant height	12.4	37.4	82.4	0.4	<.001**
Leaf blade length	7.1	16.0	29.4	0.4	<.001**
Leaf blade width	2.5	8.6	20.1	0.6	<.001**
Fruit length	1.7	7.1	15.9	0.6	0.02*
Fruit breadth	1.5	5.0	9.8	0.5	NS
Fruit weight	1.3	30.5	156.7	1.6	NS
No. of fruits per plant	2.0	44.1	377.0	4.5	NS

**=Highly significant, *=Significant, NS=Not significant, SED=Standard error of difference.
P value=Significant level test. Data are means of three replications of three plants each for the 72 African eggplant accessions, NO-Number.

Table 3.13: Quantitative trait measurements of 72 greenhouse grown African eggplant accessions with their minimum and maximum values

VARIATE	MIN	MEAN	MAX	SED	P value
Days to 50% flowering	45.0	52.7	60.0	2.0	0.045*
SPAD value	37.8	59.7	74.4	2.5	<.001**
Plant height	7.3	37.5	84.0	2.1	<.001**
Leaf blade length	6.7	16.2	28.4	0.7	<.001**
Leaf blade width	3.1	10.0	22.8	0.4	<.001**
Fruit length	1.4	7.0	15.9	0.5	<.001**
Fruit breadth	1.3	4.3	8.4	0.4	<.001**
Fruit weight	0.9	30.5	143.5	1.9	<.001**
No. of fruits per plant	2.0	43.5	360.0	2.5	<.001**

**=Highly significant, *=Significant, NS=Not significant, SED=Standard error of difference
P value=Significant level test. Data are means of three replications of three plants each for the 72 African eggplant accessions, NO-Number

3.8.7 Number of fruits per plant

No significant differences were observed among the accessions for number of fruits per plant in the field experiment. Number of fruits per plant ranged from as low as 2 fruits (accession RV100236) to 372 fruits (accession RV100453), with a mean of 44.13 fruits per plant. Seventeen accessions had a higher number of fruits than the mean (Table 3.12). Some of the accessions with

fruit number higher than the mean included accessions RV100438, RV100335, RV100360 and RV100343 having 257, 211, 203 and 140 number of fruits per accession respectively (Table 3.12). In the greenhouse experiments, there were highly significant ($P<0.01$) differences among the accessions. The mean number of fruits per accession ranged from 2 (accession RV100236) to 360 (accession RV100453), with a mean of 43.5 fruits per accession. Sixteen accessions had a higher number of fruits than the mean. Accessions with a higher fruit number than the mean included accessions RV100438, RV100360, RV100335 and RV100343 with 222, 205, 189 and 149 number of fruits per accession respectively (Table 3.13).

3.8.8 SPAD value

The accessions showed significant variation in SPAD values measured across the 72 eggplant accessions in both greenhouse and field experiment. In the field study, SPAD values ranged from 27.9 (accession RV100243) to 72.7 (accession RV100432). The mean SPAD value in the field grown accessions was 56.47 (Table 3.12). In the greenhouse, SPAD values ranged from 37.8 (accession RV100266) to 74.4 (accession RV100259). The mean SPAD value in the greenhouse grown accessions was 59.67 (Table 3.13). It is evident that accessions grown in the greenhouse had higher SPAD values than accessions grown in the field. In the field experiment, *Solanum* species accessions RV100432 had the highest SPAD value while accession RV100243 belonging to S. *aethiopicum* species had the lowest SPAD value. Accessions RV100259 and RV100266 with the highest and lowest SPAD value respectively in the greenhouse belonged to the S. *aethiopicum* species.

3.8.9 Days to 50% flowering

The accessions showed significant variation in days to 50% flowering in both greenhouse and field experiment. In the field study, days to 50% flowering ranged from 48.3 (accession RV100239) to

60.7 (accession RV100249). The mean number of days to 50% flowering in the field grown accessions was 54 days. The number of days to flowering was above average in 47 accessions (Table 3.12). In the greenhouse, number of days to 50% flowering ranged from 49 (accession RV100190) to 56 (accession RV100432). The mean number of days to 50% flowering in the greenhouse grown accessions was 53 days while 35 accessions had above average number of days to flowering (Table 3.13).

3.8.10 Correlation coefficient among the traits

Eggplant accessions showed non-significant negative correlations (-0.07 and -0.16 respectively) between days to 50% flowering and fruit length in both the greenhouse and the field (Table 3.14 and Table 3.15). Field grown accessions showed a highly significant negative (-0.27) correlation between days to 50% flowering and fruit breadth while the greenhouse grown accessions showed a non-significant negative correlation (-0.03) between the two attributes (Table 3.14 and Table 3.15). Both field and greenhouse grown accessions showed non-significant negative correlations (-0.07 and -0.16 respectively) between days to 50% flowering and fruit length. Correlations between fruit length and fruit breadth for both the field and greenhouse grown accessions showed highly significant positive correlation values (0.59 and 0.60 respectively). Both field and greenhouse grown accessions showed significant negative correlations (-0.32 and -0.31 respectively) between fruit length and the number of fruits per plant.

Table 3.14: Correlation coefficient table for the quantitative traits recorded for accessions grown in the field

TRAITS	DTF	FL	FB	FW	LBL	LBW	NOF	PH	SPAD
Days to 50% flowering	-								
Fruit length	-0.07	-							
Fruit breadth	-0.27**	0.59**	-						
Fruit weight	-0.11	0.72**	0.70**	-					
Leaf blade length	0.12	0.09	0.06	0.07	-				
Leaf blade width	-0.03	0.34**	0.18*	0.14	0.54**	-			
Number of fruits	0.21*	-0.32**	-0.47**	-0.37**	-0.03	-0.15	-		
Plant height	0.05	0.15	-0.12	-0.02	0.32**	0.13	0.13	-	
SPAD	0.08	-0.04	0.05	-0.06	0.15	0.13	-0.004	0.18*	-

DTF-Days to 50% flowering, FL-Fruit length, FB-Fruit breadth, FW-Fruit weight, LBL-Leaf blade length, NOF-Number of fruits per plant, LBW-Leaf blade width, PH- Plant height, SPAD- Soil plant analysis development. ** Correlation is highly significant at P>0.05 level,*correlation is significant at P>0.05 level

Table 3.15: Correlation coefficient table for the quantitative traits recorded for accessions grown in the greenhouse

TRAITS	DTF	FL	FB	FW	LBL	LBW	NOF	PH	SPAD
Days to 50% flowering	-								
Fruit length	-0.16	-							
Fruit breadth	-0.03	0.60**	-						
Fruit weight	-0.24**	0.73**	0.71**	-					
Leaf blade length	0.06	0.06	0.02	0.08	-				
Leaf blade width	0.07	0.28**	0.14	0.19*	0.58**	-			
Number of fruits	-0.05	-0.31**	-0.45**	-0.37**	-0.05	-0.17	-		
Plant height	0.12	0.16	-0.07	-0.03	0.28**	0.13	0.12	-	
SPAD	0.06	-0.04	-0.18*	-0.09	0.01	-0.08	0.26**	0.08	-

DTF-Days to 50% flowering, FL-Fruit length, FB-Fruit breadth, FW-Fruit weight, LBL-Leaf blade length, NOF-Number of fruits per plant, LBW-Leaf blade width, PH- Plant height, SPAD- Soil plant analysis development. ** Correlation is highly significant at P>0.05 level,*correlation is significant at P>0.05 level

A significantly negative correlations were also observed between fruit breadth and the number of fruits per plant for both field and greenhouse grown accessions (-0.47 and -0.45 respectively). Field and greenhouse grown accessions showed a highly significant negative correlation (-0.37 and -0.37 respectively) between fruit weight and number of fruits per plant.

There were highly significant positive correlation between leaf blade length and leaf blade width (0.54 and 0.58 respectively) and between the plant height and leaf blade length (0.32 and 0.28 respectively) for both the field and greenhouse grown accessions (Table 3.14 and Table 3.15).

3.9: Discussion

The study showed that majority of the accessions evaluated (88%) had upright growth habit with few having intermediate and prostrate growth habits. Prohens *et al.* (2012) made a similar observation when they characterized *S. melongena* and *S. aethiopicum* eggplant species. The upright trait is important for good vigor which enables the plant to grow to the height required for easier weeding and harvesting during production (Chowdhury *et al*., 2007). Upright growth habit facilitates free air circulation in the plant thus preventing pest and diseases attack (Chowdhury *et al*., 2007). Most accessions evaluated had white flowers (88.9%) in both the field and greenhouse. Naujeer (2009) made a similar observation for *Solanum nigrum* accessions. In the current study, some accessions had pale violet, bluish violet, light violet and greenish white flowers. Except for greenish white, accessions with these flower colours have been previously documented (FAO, 1990). The flower colour is mainly due to the pigments and biochemical compounds present in flowers; for example anthocyanin and acylglycosides (Dasgupta and De, 2007). These pigments that occur in flowers aid in pollination and subsequent fruit production (Dasgupta and De, 2007).

The study showed that leaf hairs and leaf prickles are very important marker traits for classification of African eggplant into different species. Accessions that were known for their leaf hairs and leaf prickles were RV1001201, RV100185, RV1000194, RV100234, RV100241, RV100246, RV100250, RV100261, RV100262 and RV100263. It was evident that leaf hairs were more pronounced in plants growing in the field than those growing in the greenhouse. Leaf prickles and hairs in eggplant are important in preventing insect attack on the plants. They interfere with the

feeding by herbivores due to the stiffness and irritability to the palate (Subbash, 2010). The leaf hairs also reduce transpiration, a dense coating of leaf hairs reflects sunlight thus protecting the more delicate tissues underneath in hot and dry environments (Subbash, 2010). Nevertheless, farmers prefer non-prickled leaf types for ease of harvest as stated by Chowdhury *et al*. (2007).

The qualitative characters showed high diversity indices in both field and greenhouse grown accessions. Growth habit, leaf hairs, leaf prickles, fruit shape, flower colour, fruit position, fruit length and fruit breadth showed high diversity indices, ranging from 0.9523 (leaf hairs) to 0.9941 (fruit position). The total diversity index varied from 0.9951 (greenhouse) to 0.9955 (field). Thuy (2002) and Uddin *et al.* (2014) classified the diversity of eggplant based on morphological characters as high (H'=> 0.750), moderate (H'=0.50-0.75) and low (H'=<0.50) diversity. Given that morphological characters vary with the environment, uses of molecular markers such as simple sequence repeat (SSR) are advisable to identify polymorphism trait that is not influenced by the environment (Stachel *et al.*, 2000).

Cluster analysis elaborated the existence of diversity among the 72 eggplant accessions for the morphological traits studied. The clustering pattern showed that accessions from the same species showed very close relationship with each other on the basis of Euclidean distance. The clustering patterns based on UPGMA and principal coordinate analysis were similar and established clear cut groupings based on the species of the accessions (S. *aethiopicum*, S. *anguivi*, S. *macrocarpon* and *Solanum* species) for both the field and greenhouse experiments. This study clearly showed that qualitative traits like plant growth habit, leaf prickles, leaf hairs, flower colour, fruit position and fruit shape scored the same both in the field and in the greenhouse but the difference was seen in fruit breadth and fruit length. Studies have shown that additive gene action is responsible for much of the genetic variation of the qualitative traits (Zaveri *et al*., 1980; Wasonga, 2014). Contrary to

other authors some reports indicate that action by non-additive genes and interactions between genotypes and environment are important in some situation for the variation (Singh and Rachie, 1985).

Accessions used in this study for the field and greenhouse experiments were grouped according to their species. Cluster I of the field grown accessions grouped the closely related S. *aethiopicum* accession, some S. *anguivi* and some *Solanum* species accessions together. Cluster II of field grown accessions were mostly made up of small sized fruits. Accessions in sub cluster 'c' comprised most of S. *anguivi*, some *solanum* species accessions and the only S. *macrocarpon* accession in the study plus a few of S. *aethiopicum* accessions found in sub cluster 'd'. The clustering of accessions in different groups may be useful to provide a basis for further crop improvement in eggplant (Uddin *et al.*, 2014). In the present study multivariate principal component analysis identified six traits namely leaf hairs, leaf prickles, fruit position, fruit shape, fruit breadth and flower colour as the most important traits for characterization of eggplant accessions. Multivariate principal component analysis has been previously used to identify the most important traits for characterizing genotypes and accessions of different species including pigeon pea (Upadhyaya *et al*., 2007), sweet potato (Yada *et al*., 2010), wheat (Al khanjari *et al.*, 2008) and spider plant (Wasonga, 2014).

Significant variations in quantitative traits such as fruit length, fruit breadth, leaf blade length, leaf blade width, plant height, SPAD value and days to 50% flowering were observed in this study. Uddin *et al.* (2014) made a similar observation in a study in which they evaluated eggplant accessions. Variation shown among the African eggplant accessions studied could partly be attributed to different evolutionary pathways of development. Adaptation to local environment across generations appears to have generated a significant degree of differentiation at both inter

and intra specific levels in eggplant. The same was reported in Italian pepper landraces by Portis *et al*. (2006). Fruit parameters like fruit length, fruit breadth fruit weight and fruit yield revealed a highly significant correlation with each other suggesting that increase or decrease in one parameter directly influences the increase or decrease in the other character. Chattopadhyay *et al.* (2011) made similar observation in a study of fruit weight and fruit breadth of eggplant. In the present study accessions with larger fruits included GBK 050572, RV1001201, RV100328, R100445 and RV100331, those with wider fruits included RV100200, RV100274, RV100300, RV100328 and RV100331 and accessions with heavier fruits included RV1001201, RV100200, RV100445, RV100331, RV100452, RV100328, RV100236 and RV100268. The relationship between leaf size and fruit size was not significant in the current study, which is in agreement with other researchers (Uddin *et al*., 2014). According to Kumar *et al.* (2008) high positive correlation between yield, a complex and polygenic trait with low heritability, and other heritable component traits such as leaf and fruit characters can assist in selection and breeding of high yielding varieties.

There was a highly significant positive correlation between the number of fruits per plant and SPAD value in the greenhouse. The SPAD value is proportional to the amount of chlorophyll concentration present in the sampled leaf (Jarvis, 2008). In both field and greenhouse grown accessions SPAD value was positively correlated to plant height. High SPAD reading translates to high chlorophyll content leading to high photosynthetic rate and increased translocation of photosynthates to the fruits.

Major breeding objectives in eggplant crops are to improve yield and enhance fruit quality. It is extremely important to collect, evaluate and conserve these local genotypes, wild species, landraces and exotic germplasm to develop strong and successful breeding programmes.

3.10: Conclusion

High levels of variation were observed among the morphological and agronomic traits of eggplant accessions evaluated. The wide genetic variation indicates potential for genetic improvement of the crop through selection and cross breeding. Leaf hairs, leaf prickles, flower colour, fruit shape, fruit position and fruit breadth are the key identified traits that that could be used in characterizing eggplant accessions.

CHAPTER FOUR: EFFECT OF WATER STRESS ON GROWTH, YIELD AND NUTRITIONAL QUALITY OF SELECTED AFRICAN EGGPLANT ACCESSIONS

4.1 Abstract

Drought stress is one of the main factors limiting productivity of crops in Kenya. Cultivation of neglected and underutilized indigenous crop species such as African eggplant has the potential to reduce the adverse effects of drought. However, there is limited information on the impact of drought on the productivity and quality of African eggplant. A study was conducted at the University of Nairobi's Field Station to determine the effect of water stress on growth, yield and nutritional quality of 20 selected African eggplant accessions. The accessions were subjected to different moisture levels (40, 60 and 80% field capacity) and adequately watered (100% field capacity) conditions. The experiments were set up in a greenhouse and laid out in a randomized complete block design with three replications. Data was collected on growth traits (plant height, stem girth, single leaf area and fruit weight), physiological characters (stomatal conductance, canopy temperature, leaf relative water content and chlorophyll content) and chemical components (β-carotene, vitamin C, total soluble solids, titratable acidity, pH, magnesium, calcium, iron and zinc) measured at vegetative, flowering and fruit maturity stages. Water stress significantly decreased fruit yield (16.6%), fruit weight (13.8%), stem girth (31.9%), plant height (20.1%), single leaf area (17.9%), stomatal conductance (57.7%), leaf relative water content (37.2%), chlorophyll content (12.6%), pH (6%), magnesium (43.5%), calcium (43.9%), iron (47.3%) and zinc (18.9%). However, it increased β-carotene concentration (29.5%), vitamin C (6%), titratable acidity (16.7%), total soluble solids (14.9%) and canopy temperature (19.7%). Water stress decreased growth and fruit yield parameters, Ca, Mg, Fe and Zn but increased β-carotene, vitamin C and total soluble solids. Response to drought stress with respect to growth, yield, physiological

and nutritional quality was dependent on accessions indicating their potential use in eggplant improvement programmes.

4.2 Introduction

Eggplant is eaten as a vegetable and it is a major source of nutrients (e.g. Ca, Fe, Zn, Mg, β-carotene and vitamin C) essential for a healthy diet. It produces bioactive components and antioxidants such as fruit phenols and flavonoic constituents (Singh *et al.,* 2009; Umesh *et al.,* 2015). The eggplant fruit peel contains high content of delphinidin while its flesh contains chlorogenic acid (Umesh *et al.,* 2015). These biochemical compounds have a potential to help in the management of cancer, high blood pressure and hepatosis (Magioli and Mansur, 2005; Umesh *et al.,* 2015).

According to HCDA (2013), Kenya produced 9,447 metric tonnes of eggplant in the year 2013, however, the productivity of the crop is reduced by several constraints including drought stress. Drought stress is widely experienced particularly in rain fed agricultural land estimated at 1.2 billion hectares globally (Passioura, 2007; Amiri *et al* 2011). About 70% of Kenya's land mass is affected by drought leading to high vulnerability to food insecurity particularly in the arid and semi-arid lands (ASALs) of the country (Hugo *et al.,* 2010). Drought events associated with climate change and climate variability have become more pronounced in Kenya in recent years, adversely affecting agricultural production (Hugo *et al.,* 2010). Severe droughts can cause up to 60 to 100% yield losses in different crop species (Singh *et al.,* 2002; Amiri *et al*., 2011). This calls for crop species and varieties with high tolerance levels to drought. African eggplant, comprising *Solanum aethiopicum, Solanum anguivi* and *Solanum macrocarpon* is less susceptible to drought hence its yield losses under drought stress are expected to be low compared to the commercial eggplant. To improve the productivity of eggplant in drought prone Kenyan environments requires

drought tolerance breeding programs. Hence, there is a need to identify drought tolerant genotypes from existing African eggplant germplasm which could provide sources of genes for genetic improvement of this crop.

It has been reported that water stress may significantly reduce macronutrient concentrations of eggplant and increase concentrations of vitamin C, β-carotene and total soluble solids (Kirnak *et al.,* 2001). The impact of water stress on nutritional quality of African eggplant has not been evaluated. The objective of this study was to determine the effects of water stress on growth, yield and nutritional quality of 20 selected African eggplant accessions.

4.3 Materials and methods

4.3.1 Site Description

The experiments were conducted in a greenhouse at Kabete Field Station University of Nairobi, Kenya. The site is located on the latitudes 1^0 14′ 20″ to $1^0$15′15″ South and longitudes 36^0 44′ to 36^0 45′ East, at an altitude of 1940 meters above sea level. The first greenhouse experiment was carried out from 18th March 2015 until 30th August 2015 while the second greenhouse experiment lasted from 29th April 2015 up to 25th September 2015. The long rains occur from early March to late May, whereas short rains occur from October to December. The site has minimum and maximum mean annual temperature of 13^0C and 23^0C, respectively (Siderus, 1976). Prior to planting, soil was sampled and analyzed for soil pH, nitrogen, organic carbon, phosphorus, potassium, calcium, magnesium, manganese, copper, iron, zinc and sodium content at the National Agricultural Research Laboratories (Table 3.1 in chapter three of this thesis).

4.3.2 Planting materials

Twenty (20) African eggplant accessions consisting of 14 from *Solanum aethiopicum*, 4 from *Solanum* species and 2 from *Solanum anguivi* were used in this study (Table 4.1). Nineteen (19) of the accessions were sourced from the Asian Vegetable Research Development Centre (AVRDC) based in Arusha (Tanzania) and Taiwan and one breeders' line accession sourced from the National Gene Bank of Kenya in Muguga. The 20 accessions were selected based on their place of origin, type of species, fruit weight and fruit quantity, leaf size, presence of leaf prickles, presence of leaf hairs, time to 50% flowering and SPAD value.

Table 4.1: List of plant materials provided by Asian Vegetable Research and Development Center East and Southern Africa (AVRDEC- ESA)

S/no	RVI code	Genus	Species	Name	Origin
1	RVI00161	*Solanum*	*aethiopicum*	MANYIRE GREEN	Tanzania
2	RVI00270	*Solanum*	*aethiopicum*	86	Mali
3	RVI00263	*Solanum*	*aethiopicum*	119	Mali
4	GBK 050572	*Solanum*	*aethiopicum*	MAFWA	Kenya
5	RVI00386	*Solanum*	*aethiopicum*	EX-IVORY COAST	Ivory Coast
6	RVI00377	*Solanum*	*aethiopicum*	EX-SIRONKWOO	Uganda
7	RVI00327	*Solanum*	*aethiopicum*	AUBERGINE BLANCH	Mali
8	RVI00334	*Solanum*	*aethiopicum*	SOXNA	Mali
9	RVI00511	*Solanum*	*aethiopicum*	SENGEREMA 1	Tanzania
10	RVI00331	*Solanum*	*aethiopicum*	L10	Unknown
11	RVI00352	*Solanum*	*aethiopicum*	RW-AE-13	Uganda
12	RVI00328	*Solanum*	*aethiopicum*	LOCAL MALI	Mali
13	RVI00242	*Solanum*	*aethiopicum*	103	Mali
14	RVI00169	*Solanum*	*aethiopicum*	TENGERU WHITE	Tanzania
15	RVI00190	*Solanum*	*anguivi*	N19	Tanzania
16	RVI00364	*Solanum*	*anguivi*	UG-AE-20	Uganda
17	RVI00453	*Solanum*	Species	S00052	Unknown
18	RVI00382	*Solanum*	Species	BORY BORY	Madagascar
19	RVI00452	*Solanum*	Species	S0005	Unknown
20	RVI00458	*Solanum*	Species	S001381	Unknown

RVI- Accession registration code used in AVRDEC

4.4 Experimental design and crop husbandry

Twenty (20) accessions of African eggplant were evaluated for drought tolerance against four moisture levels (100%, 80%, 60% and 40% field capacity) in pots set up in a greenhouse. The treatments were laid out in a randomized complete block design with a factorial arrangement with three replications. Two seedlings were planted per pot and later thinned to one seedling per pot when the plants were at 25 cm above ground. Each pot was 36.5 cm long x 18.5 cm wide. Pots were filled with a mixture of sterilized Kabete humic nitisols soil. One part of sand was mixed with two parts of soil and two parts of compost (ratio 1: 2: 2) before filling in the pots. The pots were each filled with 7 kg of air-dried soil mixture. One teaspoon of calcium ammonium nitrate equivalent to 9.8 grams per seedling was applied in each pot just before planting. Seedlings that had been raised in trays in the greenhouse for four weeks were then transplanted into the pots. Irrigation was done before and after transplanting of the seedlings.

Before initiating water stress treatments, the 20 accessions were irrigated to field capacity for two weeks in order to improve root development. Soil water potential was monitored using a tensiometer at 13 cm depth. The tensiometers were calibrated to measure the actual availability of water in the soil. As soon as soil water potential reached – 8 kPa, plants were watered to field capacity using a watering can. The crops were then top dressed six weeks later with 19.6 grams per plant of calcium ammonium nitrate. The plants were sprayed with Actara® (active ingredient thiomethoxam), Karate® (active ingredient lambda cylothrin) and Ortiva® (active ingredient 250 g/l azoxystrobin) insecticides at the rate of 20 g per 20 litres of water at 20, 40 and 55 days after emergence to control whiteflies, thrips and aphids. Pots were kept weed free by hand weeding.

4.5 Data collection

4.5.1 Growth parameters

Growth data were collected on plant height, single leaf area and stem girth. All measurements and counts of a given trait were done on the same day for all the grown accessions in order to maintain uniformity. Total yield was measured at harvesting when the fruits were mature and have changed colour from green to the final ripe colour of specific accession fruit.

Plant height was measured (in centimeters) from the base of the plant to the tip of the main stem using a meter rule at flowering stage. The stem girth (cm) was determined by measuring the circumference of the middle portions of the stems of three plants at flowering stage. Three young fully expanded leaves from the three selected plants per accession were randomly selected at flowering and leaf length measured (in centimeters) from the pulvinus to the tip of the leaf while leaf width (cm) was measured at the widest part of the basal leaves. The single leaf area (cm^2) was calculated using leaf length and leaf width measurements following the formulae of Rivera *et al*. (2007): SLA=0.763L +0.34W, where SLA is single leaf area, L is leaf length and W is leaf width.

4.5.2 Physiological parameters

Stomatal conductance, leaf relative water content, canopy temperature and chlorophyll content were measured at vegetative stage based on three selected plants per plot. The leaf chlorophyll content was taken at flowering stage on a fully expanded young leaf in every three plants. This value was taken using a non-destructive, handheld chlorophyll meter called Soil Plant Analysis Development (SPAD-502, Minolta camera Co., Ltd., Japan). SPAD -502 determines the relative amount of chlorophyll present in the leaf by measuring the transmittance of the leaf in two bands namely 600 nm to 700 nm and 400 nm to 500 nm. SPAD-502 measures the absorbance of the leaf in the red and near infrared regions.

Relative water content (RWC) is the appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit. The leaf relative water content (LRWC) was calculated based on the methods of Yamasaki and Dillenburg (1999). The young leaves were picked from the mid-section of a plant. A leaf sample was made up of three leaves, collected from the same plant, and then weighed to obtain the fresh mass (FM). The turgid mass (TM) was recorded when the same leaves were floated in distilled water inside a closed petridish for 24 hours and after gently wiping the water from the leaf surface with tissue paper. After the imbibition period, the dry mass (DM) was taken after the leaf samples were placed in a pre-heated oven at 60^0C for 48 hours. All mass measurements were made using an analytical scale, with precision of 0.001 g. Values of FM, TM, and DM were used to calculate LRWC, using the equation: LRWC(%) = [(FM – DM)/(TM – DM)] x 100 (Aguyoh *et al.*,2013).

Stomatal conductance (mmol/m^2s) was taken at flowering stage on three fully expanded young leaves per plants. The stomatal conductance was measured using a leaf porometer (Decagon Devices, Inc). Crop canopy temperatures were measured with an infrared thermometer (Teletempt Model AG-42). Measurements were made when stress was considered to be maximal (11:00–13:00 h) by shining the infrared light on young fully grown leaves of three selected accessions.

4.5.3 Chemical components of the fruits

The chemical components of fruits that were determined included total soluble solids, titratable acidity, pH, β-carotene, vitamin C and minerals.

4.5.3.1 Total soluble solid

Total soluble solids (TSS) were determined on three fruit samples taken randomly from harvested fruits in each of two water stress levels (100% FC and 60% FC). Three milliliter juice was extracted

from three fruit samples and the TSS determined using a handheld digital refractometer (Model 500, Atago Co., Ltd and Tokyo, Japan) and expressed as ^{o}brix.

4.5.3.2 Titratable Acidity

Titratable acidity (TA) was determined on three fruit samples representing each accession randomly selected from harvested fruits from each of the water stress levels (100% FC and 60% FC). The fruits were crushed using pestle and mortar to get juice. Thereafter, 0.3 ml of indicator (1% phenolphthalein in 95% ethanol) was added to 10ml of the extracted juice. The extracted juice was then diluted with 50 ml distilled water and titrated with 0.1 N sodium hydroxide to a permanent pink colour and a final titrant noted. The percentage TA was expressed using the following equation:

Equation 4.1

$$\text{Titratable acidity \%} = \frac{\text{Vol. of 0.1 N NaOH used x conversion Factor x 100}}{\text{Volume of sample used}}$$

Citric acid's conversion factor = 0.064

4.5.3.3 pH

The pH was determined on three fruit samples representing each accession randomly selected from harvested fruits from each of the water stress levels (100% FC and 60% FC). The fruits were mashed using pestle and mortar into juice and the pH was measured using a pH meter. The pH meter was standardized with a standard pH buffer solution of 4.0. The electrode was rinsed with distilled water, blotted and then standardized using the alkaline buffer solution of 9.18 and finally the pH of the sample juice was measured.

4.5.3.4 Determination of β-carotene content

The β-carotene content was determined by a modified chromatographic procedure (Heinonen, 1990). Five grams of the fruit sample were put in a mortar then a spatula full of celite was added

to the sample in the mortar and crushed using a pestle. The juice extract was mixed with 50 ml of cold acetone and filtered using a glass funnel until the residue was completely washed to white. Partitioning was done using 25 ml petroleum ether in a separating funnel to obtain the β-carotenerich upper layer. Distilled water (200 ml) was then added along the walls of the funnel. The two phases were separated and the lower aqueous phase discarded. Acetone residues were removed by washing three times with distilled water without discarding the upper phase. The mixture was washed with distilled water until it was clean and then anhydrous sodium sulphate was used to drain water and finally the extract was stored in sample bottles in a dark cabinet. β-carotene content was determined using ultraviolet visible spectrophotometer (Model UV mini 1240, Kyoto Shimadzu) and absorbance read at 450 nm. The β−carotene content was calculated using the following equation:

$$\textbf{β−carotene (mg/100ml)} = \frac{\text{A X Volume (ml) x } 10^4}{A^{1\%}1\text{cm x sample weight (g)}}$$

Where A= absorbance; volume = total volume of extract (25 ml); $A^{1\%}_{1cm}$ = absorption coefficient of β−carotene in petroleum ether =2592 (Rodriguez-Amaya and Kimura, 2002).

4.5.3.5 Ascorbic acid determination (Vitamin C)

The ascorbic acid content in the sample was determined by the high-performance liquid chromatography (HPLC) method (Vikram *et al*., 2005). Five grams of the sample was weighed and extracted with 0.8% metaphosphoric acid. This was made to 20 ml juice. The juice was centrifuged at 100 rpm for 10 minutes. The supernatant was filtered and diluted with 10 ml of 0.8% metaphosphoric acid. This was then filtered using cotton wool, micro-filtered through 0.45 µ filter and 20 µL injected into the HPLC machine. Various concentrations of ascorbic acid standards were

also made to make a calibration curve. HPLC analysis was done using Shimadzu UV-VIS detector. The mobile phase was 0.8% metaphosphoric acid, at 1.1 mL/min flow rate and wavelength of 266.0 nm.

4.5.3.6 Determination of minerals

Minerals were analyzed using the AOAC (1996) method. Five grams of the pulp was charred in the oven for 30 minutes and then put in a muffle furnace at 550^0C for eight hours to ash. The ash was allowed to cool and diluted with 10 ml of 1 N hydrochloric acid. The mixture was filtered and diluted with 100 ml of distilled water. Calcium, iron, zinc and magnesium were analyzed using an atomic absorption spectrophotometer (Model AA-6200, Shimadzu Corp., Kyoto, Japan). Before analysis the samples of Ca were further diluted with 5 ml of water while those of Mg were diluted with 20 ml of water. Iron and zinc samples were not diluted. The absorbance of the solutions was read by Atomic Absorption Spectrophotometer (AAS). The various mineral standards were also prepared to make the calibration curves.

4.6 Data analysis

Analysis of variance (ANOVA) was performed on the data collected using Genstat version 14 (Payne *et al.,* 2011) at 5% level of significance. Mean separation for treatment effects that were significant was done by Fisher's protected least significant difference (LSD) test using Genstat version 14 at $P \leq 0.05$.

4.7 Results

4.7.1 Plant height and single leaf area

Accession, moisture level and accession x moisture level significantly affected the plant height and single leaf area (Table 4.2). Reduction of moisture level from 100% field capacity (FC) to 60%, or less, field capacity significantly reduced plant height and single leaf area for all the accessions. Water stress reduced plant height by 9.6, 15.9 and 20.1% at 80, 60 and 40% FC, respectively, as compared to the control (100% FC). The decline in plant height ranged from 34% (Accession RV100263) to 12.7% (accession RV100190). The average plant height ranged from 41.7 cm (40% FC) to 52.2 cm (100% FC). The decline in single leaf area ranged from 9.4% (accession RV100386) to 29.5% (accession RV100263). The average single leaf area ranged from 20.4 cm^2 (40% FC) to 24.9 cm^2 (100% FC).

4.7.2 Stem girth

Accession, moisture level and accession x moisture level significantly affected the stem girth (Table 4.3). The reduction in stem girth with a decline in moisture level from 100% to 80% FC, 80% to 60% FC and 60% to 40% FC varied from 5.4 (accession RV100161) to 28.9% (accession GBK 050572), 2.4 (accession RV100452) to 20% (accession RV100190) and 3.8 (accession RV100386) to 37.5% (accession RV100452). The average decline in stem girth varied from 0.7 cm in accession RV100386 to 2.1 cm in accession GBK 050572 with decline in moisture level from 100% to 40% FC.

Table 4.2: Effects of moisture level (% field capacity) on plant height (cm) and single leaf area (cm^2) of 20 African eggplant accessions

		Plant height					Single leaf area				
S/no	**Acc. Codes**	***100%**	**80%**	**60%**	**40%**	**Mean**	***100%**	**80%**	**60%**	**40%**	**Mean**
1	GBK050572	52.2	49.3	47.6	44.6	**48.4**	34.4	32.7	31.5	30.5	**32.3**
2	RV100161	41.9	38.7	36.4	34.7	**37.9**	24.4	22.6	21.9	20.6	**22.4**
3	RV100169	64.0	58.3	51.5	47.2	**55.3**	24.5	21.9	20.3	18.9	**21.4**
4	RV100190	66.8	63.3	60.7	58.3	**62.3**	27.1	24.7	22.9	21.8	**24.1**
5	RV100242	50.1	42.3	38.2	37.0	**41.9**	19.9	17.8	16.5	15.9	**17.5**
6	RV100263	57.9	45.0	40.9	38.2	**45.5**	29.8	23.5	22.6	21.0	**24.2**
7	RV100270	40.4	34.9	30.1	27.5	**33.2**	25.2	20.8	18.5	17.3	**20.5**
8	RV100327	46.1	42.7	39.2	37.2	**41.3**	24.7	23.0	21.7	20.3	**22.4**
0	RV100328	51.0	48.1	44.8	43.2	**46.8**	25.2	23.7	22.3	21.1	**23.1**
10	RV100331	40.1	37.9	35.7	34.1	**37.0**	28.9	27.2	25.8	24.5	**26.6**
11	RV100334	48.1	43.3	38.5	36.0	**41.5**	25.9	24.1	22.6	21.2	**23.5**
12	RV100352	39.4	34.1	31.9	29.4	**33.7**	20.2	18.1	17.6	16.5	**18.1**
13	RV100364	68.5	63.2	58.4	56.3	**61.6**	29.0	25.8	23.7	22.2	**25.2**
14	RV100377	62.5	56.8	55.3	53.5	**57.0**	25.7	24.4	23.4	21.9	**23.9**
15	RV100382	64.6	60.0	54.7	51.7	**57.7**	26.3	25.3	24.0	22.9	**24.6**
16	RV100386	31.3	28.8	26.4	25.6	**28.0**	17.0	16.9	16.3	15.4	**16.4**
17	RV100452	38.1	34.7	31.8	30.5	**33.8**	26.1	24.6	23.8	22.3	**24.2**
18	RV100453	64.1	59.5	56.8	54.2	**58.7**	16.7	15.3	15.0	13.6	**15.2**
19	RV100458	77.1	66.9	62.6	60.3	**66.7**	20.5	19.0	18.4	17.6	**18.9**
20	RV100511	40.2	36.3	35.9	33.7	**36.5**	25.6	23.7	22.6	22.1	**23.5**
	Mean	**52.2**	**47.2**	**43.9**	**41.7**		**24.9**	**22.8**	**21.5**	**20.4**	
	P Value (A)		**<.001**					**<.001**			
	P Value (ML)		**<.001**					**<.001**			
	P Value (A x ML)		**<.001**					**<.001**			
	Lsd (A)		**1.20****					**0.59****			
	Lsd (ML)		**0.54****					**0.30****			
	Lsd (A x ML)		**2.40****					**1.17****			
	CV%		**3.20**					**3.20**			

LSD- Least significant difference, ** Highly significant, * Significant, ns- Not significant, *100% field capacity,80% field capacity, 60% field capacity and 40% field capacity. A-accession, ML- moisture level

Table 4.3: Effects of moisture level (% field capacity) on stem girth (cm) of 20 African eggplant accessions

		Stem girth				
S/no	**Acc. Codes**	***100%**	**80%**	**60%**	**40%**	**Mean**
1	GBK050572	4.5	3.2	2.8	2.4	**3.2**
2	RV100161	3.8	3.5	3.3	2.6	**3.3**
3	RV100169	3.5	3.0	2.7	2.3	**2.9**
4	RV100190	3.7	3.5	2.8	2.4	**3.1**
5	RV100242	4.2	3.8	3.5	2.9	**3.6**
6	RV100263	4.3	3.9	3.4	2.9	**3.6**
7	RV100270	4.5	3.9	3.6	3.3	**3.8**
8	RV100327	4.2	3.7	3.4	2.6	**3.5**
0	RV100328	4.6	3.7	3.3	2.6	**3.6**
10	RV100331	4.2	3.6	3.5	2.9	**3.6**
11	RV100334	3.5	2.9	2.8	2.5	**2.9**
12	RV100352	4.1	3.7	3.5	2.9	**3.6**
13	RV100364	4.4	4.0	3.6	3.3	**3.8**
14	RV100377	4.2	3.6	3.1	2.9	**3.5**
15	RV100382	3.9	3.6	3.3	2.7	**3.4**
16	RV100386	3.2	2.7	2.6	2.5	**2.8**
17	RV100452	4.4	4.1	4.0	2.5	**3.8**
18	RV100453	4.1	3.6	3.2	2.9	**3.5**
19	RV100458	4.1	3.7	3.5	3.1	**3.6**
20	RV100511	3.6	3.4	3.1	2.8	**3.2**
	Mean	**4.04**	**3.55**	**3.25**	**2.75**	**3.42**
	P Value (A)			**<.001**		
	P Value (ML)			**<.001**		
	P Value (A x ML)			**0.006**		
	Lsd (A)			**0.22****		
	Lsd (ML)			**0.10****		
	Lsd (A x ML)			**0.44****		
	CV%			**8.00**		

LSD- Least significant difference, **Highly significant, * Significant, ns- Not significant, *100% field capacity, 80% field capacity, 60% FC and 40% field capacity. A-accession, ML- moisture level.

4.7.3 Fruit weight

Accession, moisture level and accession x moisture level significantly influenced the weight of eggplant fruit (Table 4.4). Reduction of water level from 100% to 40% FC significantly reduced fruit weight in all accessions. Reduction of water level from 100% to 80%, 80% to 60% and 60% to 40% FC significantly decreased fruit weight in 14, 8 and 4 accessions respectively. The reduction in fruit weight with the decline in moisture level from 100% to 80% FC, 80% to 60% FC and 60% to 40% FC varied from 0.1 (accession RV100453) to 9.8 g (accession RV100452), 0.5 (accession RV100364) to 4.7 g (accession RV100386) and 0.2 (accession RV100453) to 2.7 g (accession RV100331) respectively.

4.7.4 Fruit yield

Accession, moisture level and accession x moisture level significantly affected the fruit yield of eggplant (Table 4.4). Reduction of moisture level from 100% to 80% FC, 80% to 60% FC, and 60% to 40% FC significantly reduced the yield in 17, 15 and 15 accessions respectively. The reduction in fruit yield with the decline in moisture level from 100% to 80% FC, 80% to 60% FC and 60% to 40% FC varied from 0.1 (accession RV100364) to 4.9 t/ha (accession RV100452), 0.3 (accession RV100453) to 2.4 t/ha (accession RV100386) and 0.1 (accession RV100453) to 1.3 t/ha (accession RV100386) respectively. Accessions that were least significantly affected by water stress at 40% FC were RV100364, RV100453, and RV100190. Fruit yield ranged from 1.6 (accession RV100453) to 39.3 t/ha (accession RV100452). Accessions RV100452, RV100327 and GBK050572 had the highest mean fruit yields of 39.2, 38.2 and 28.9 t/ha, respectively, compared to all other accessions.

Table 4.4: Effects of moisture level (% field capacity) on fruit weight (g/plant) and yield (t/ha) of 20 African eggplant accessions

		Fruit weight (g/plant)					Yield (t/ha)				
S/no	**Accessions**	***100%**	**80%**	**60%**	**40%**	**Mean**	***100%**	**80%**	**60%**	**40%**	**Mean**
1	GBK050572	61.6	58.4	56.5	54.4	**57.7**	30.8	29.2	28.3	27.2	**28.9**
2	RV100161	40.3	36.7	35.1	33.8	**36.5**	20.1	18.3	17.5	16.9	**18.2**
3	RV100169	29.3	27.1	26.0	24.7	**26.8**	14.7	13.6	13.0	12.4	**13.4**
4	RV100190	5.6	5.1	4.5	3.6	**4.7**	2.8	2.6	2.3	1.8	**2.4**
5	RV100242	30.7	25.6	24.6	22.8	**26.0**	15.4	12.8	12.3	11.4	**13.0**
6	RV100263	22.8	20.1	19.1	18.7	**20.2**	11.4	10.0	9.6	9.4	**10.1**
7	RV100270	44.9	38.8	35.3	33.6	**38.2**	22.5	19.4	17.7	16.8	**19.1**
8	RV100327	80.7	77.3	74.3	73.6	**76.5**	40.3	38.7	37.2	36.8	**38.2**
0	RV100328	31.1	28.6	27.5	26.4	**28.4**	15.6	14.3	13.8	13.2	**14.2**
10	RV100331	70.7	69.7	67.4	64.7	**68.1**	35.3	34.8	33.7	32.4	**34.1**
11	RV100334	33.6	31.5	29.5	28.0	**30.6**	16.8	15.8	14.7	14.0	**15.3**
12	RV100352	28.2	24.6	22.8	22.1	**24.4**	14.1	12.3	11.4	11.0	**12.2**
13	RV100364	5.7	5.5	5.0	4.1	**5.1**	2.8	2.8	2.5	2.1	**2.5**
14	RV100377	32.3	30.7	29.8	28.1	**30.3**	16.2	15.4	14.9	14.1	**15.1**
15	RV100382	27.6	25.8	24.4	23.1	**25.2**	13.8	12.9	12.2	11.6	**12.6**
16	RV100386	39.4	36.4	31.7	29.2	**34.2**	19.7	18.2	15.9	14.6	**17.1**
17	RV100452	88.1	78.3	74.5	73.5	**78.6**	44.0	39.2	37.3	36.7	**39.3**
18	RV100453	3.6	3.5	2.9	2.7	**3.2**	1.8	1.8	1.5	1.3	**1.6**
19	RV100458	23.0	19.7	18.3	17.2	**19.5**	11.5	9.9	9.2	8.6	**9.8**
20	RV100511	14.5	12.6	11.9	11.0	**12.5**	7.2	6.3	5.9	5.5	**6.2**
	Mean	**35.7**	**32.8**	**31.1**	**29.8**		**17.8**	**16.4**	**15.5**	**14.9**	
	P Value (A)		**<.001**					**<.001**			
	P Value (ML)		**<.001**					**<.001**			
	P Value (A x ML)		**<.001**					**<.001**			
	Lsd (A)		**0.88****					**0.22****			
	Lsd (ML)		**0.39****					**0.10****			
	Lsd (A x ML)		**1.75****					**0.44****			
	CV%		**3.40**					**3.40**			

LSD- Least significant difference, **Highly significant, * Significant, ns- Not significant, *100% field capacity, 80% field capacity, 60% FC and 40% field capacity, A-accession, ML- moisture level.

4.7.2 Physiological parameters

4.7.2.1 Stomatal conductance

Accession, moisture level and accession x moisture level significantly influenced the stomatal conductance (Table 4.5). Reduction of moisture level from 100% to 80% FC, 80% to 60% FC and 60% to 40% FC resulted in reduction of stomatal conductance by 6.9 (accession RV100334) to 27.8% (accession GBK050572), 7.8 (accession RV100377) to 45.4% (accession RV100334) and 11.6 (accession RV100327) to 65.8% (accession GBK05072) respectively. The average stomatal conductance ranged from 404.4 mmol $m^{-2}s^{-1}$ (100% FC) to 171.0 mmol $m^{-2}s^{-1}$ (40% FC). All the accessions, except RV100328, had significantly lower stomatal conductance at 80, 60 and 40% FC relative to the control (100% FC). Water stress decreased the mean stomatal conductance by 19.2, 37.4 and 57.7% at 80%, 60% and 40% FC respectively. The mean stomatal conductance ranged 168.6 mmol $m^{-2}s^{-1}$ (accession RV100263) to 415.6 mmol $m^{-2}s^{-1}$ (RV100458).

4.7.2.2 Canopy temperature

Accession, moisture level and accession x moisture level significantly affected the canopy temperature(Table 4.5).Reduction of moisture level from 100% to 80% FC, 80% to 60% FC and 60% to 40% FC significantly increased the canopy temperature in 14, 12 and 7 accessions respectively. The increase in canopy temperature with the decline in moisture level from 100% to 80% FC, 80% to 60% FC and 60% to 40% FC varied from 0.7 (accession RV100452) to 2.4^0C (accession RV100377), 0.6 (accession RV100382) to 3.2^0C (accession RV100263) and 0.6 (accession GBK05072) to 3.1^0C (accession RV100161) respectively. At 60% and 40% FC all accessions had significantly lower stomatal conductance than at 100% FC. However, at 80% FC stomatal conductance of accessions GBK050572, RV100161, RV100190, RV100328, RV100382 and RV100452 were not significantly different from the control (100% FC). Accession RV100377

registered the highest canopy temperature (31.4^0C) at 40% FC while accession RV100270, RV100242 and RV100364 with (22.4^0C) had the lowest canopy temperature at 100% FC.

Table 4.5: Effects of moisture level (% field capacity) on stomatal conductance (mmol $m^{-2}s^{-1}$) and canopy temperature (^oC) of 20 African eggplant accessions

		Stomatal conductance					Canopy Temperature				
S/no	**Acc. Codes**	***100%**	**80%**	**60%**	**40%**	**Mean**	***100%**	**80%**	**60%**	**40%**	**Mean**
1	GBK050572	652.4	471.2	330.4	113.2	**391.8**	26.6	27.4	28.6	29.2	**27.9**
2	RV100161	426.9	319.6	247.2	123.7	**279.4**	22.6	23.8	26.3	29.4	**25.5**
3	RV100169	527.7	448.4	352.9	247.6	**394.1**	22.5	24.5	26.6	28.4	**25.5**
4	RV100190	423.5	375.7	311.9	231.2	**335.6**	25.0	25.6	27.3	28.2	**26.5**
5	RV100242	325.3	241.6	187.1	153.2	**226.8**	22.4	24.5	25.8	26.8	**24.9**
6	RV100263	264.9	188.0	140.3	81.2	**168.6**	25.4	27.7	30.9	32.4	**29.1**
7	RV100270	355.4	210.6	185.3	147.3	**224.7**	22.4	24.0	25.5	27.0	**24.7**
8	RV100327	372.4	312.0	265.3	234.6	**296.1**	23.6	25.0	25.9	28.5	**25.7**
0	RV100328	356.7	335.1	256.5	152.1	**275.1**	23.3	24.2	25.8	27.7	**25.3**
10	RV100331	419.9	336.4	191.4	139.3	**271.7**	22.7	24.7	25.6	26.7	**24.9**
11	RV100334	471.3	439.2	240.0	172.9	**330.8**	25.2	26.7	28.0	29.4	**27.3**
12	RV100352	322.0	218.1	157.8	96.9	**198.7**	23.9	25.5	26.4	28.4	**26.1**
13	RV100364	319.5	248.9	221.7	174.0	**241.0**	22.4	23.7	24.5	26.2	**24.2**
14	RV100377	323.9	266.6	245.9	172.3	**252.2**	26.2	28.6	30.4	31.4	**29.2**
15	RV100382	484.7	428.7	357.6	214.0	**371.3**	22.6	23.4	24.0	26.3	**24.1**
16	RV100386	340.7	284.3	253.8	161.1	**260.0**	24.6	26.7	27.5	28.7	**26.9**
17	RV100452	467.9	435.8	395.8	266.6	**391.5**	24.5	25.2	27.5	30.4	**26.9**
18	RV100453	321.1	220.2	156.0	111.1	**202.1**	23.6	25.7	27.4	28.6	**26.3**
19	RV100458	552.6	493.2	348.1	268.4	**415.6**	23.3	25.3	28.1	29.8	**26.7**
20	RV100511	359.1	260.8	219.3	158.3	**249.4**	22.6	24.6	25.3	27.4	**25.0**
	Mean	**404.4**	**326.7**	**253.2**	**171.0**		**23.8**	**25.3**	**26.9**	**28.5**	
	P Value (A)			**<.001**					**<.001**		
	P Value (ML)			**<.001**					**<.001**		
	P Value (A x ML)			**<.001**					**<.001**		
	Lsd (A)			**15.79****					**0.61****		
	Lsd (ML)			**7.06****					**0.27****		
	Lsd (A x ML)			**31.57****					**1.21****		
	CV%			**6.80**					**2.90**		

LSD- Least significant difference, **Highly significant, * Significant, ns- Not significant, 100% field capacity, 80% field capacity, 60% FC and 40% field capacity. A-accession, ML-moisture level.

4.7.2.2 Leaf relative water content (%)

Accession and moisture level significantly affected leaf relative water content, but accession x moisture level had no effect on this parameter (Table 4.6). Every 20% decrease in moisture level led to a significant decline in leaf relative water content. Accession RV100242 had significantly higher LRWC than all other accessions, except RV100169, RV100382 and RV100334. Similarly, accessions RV100328, RV100331 and RV100270 had significantly higher LRWC than over 50% of the accessions evaluated. The mean leaf relative water content ranged from 63.5 (accession RV100242) to 70.3% (accession RV100328).

4.7.2.3 Chlorophyll content

Accession, moisture level and accession x moisture level significantly affected the chlorophyll content in eggplant (Table 4.6). Reduction of moisture level from 100% to 80% FC, 80% to 60% FC and 60% to 40% FC significantly decreased SPAD value by 1.7 (accession RV100452) to 5.4% (accession RV100263), 2.7 (accession GBK100572) to 7.9% (accession RV100382) and 2.9 (accession RV100382) to 10.7% (accession RV100169) respectively. The mean chlorophyll content reduced by 12.6% from 100% FC to 40% FC. Chlorophyll content varied from 44.4% (accession RV100328) to 62.2% (accession RV100453) at 100% FC, 42.4% (accession RV100328) to 59.3% (accession RV100453) at 80% FC, 40.9% (accession RV100328) to 57.2% (accession RV100453) at 60% FC and 38.5% (accession RV100328) to 52.9% (accession RV100453) at 40% FC. Accession RV100263was the most affected by water stress with a difference of 9.8 SPAD value between 100% and 40% FC. The mean reduction in chlorophyll content compared to the control was 3.4, 7.5 and 12.6% at 80%, 60% and 40% FC respectively.

Table 4.6: Effects of moisture level (% field capacity) on leaf relative water content (%) and chlorophyll content of 20 African eggplant accessions

		LRWC %					SPAD				
S/no	**Accessions**	***100%**	**80%**	**60%**	**40%**	**Mean**	***100%**	**80%**	**60%**	**40%**	**Mean**
1	GBK050572	85.5	74.6	64.7	51.8	**69.2**	45.7	44.7	43.5	39.5	**43.4**
2	RV100161	84.4	70.8	66.3	52.7	**68.5**	48.4	46.8	43.9	41.0	**45.0**
3	RV100169	80.0	72.3	63.0	49.0	**66.1**	57.3	55.4	53.2	47.5	**53.3**
4	RV100190	83.3	73.4	64.6	54.7	**69.0**	52.9	50.7	48.2	46.4	**49.6**
5	RV100242	79.7	69.5	60.5	44.5	**63.5**	50.8	49.7	47.7	44.7	**48.2**
6	RV100263	83.3	69.7	63.7	51.0	**66.9**	53.7	50.8	46.8	43.9	**48.8**
7	RV100270	83.2	74.9	66.3	55.6	**70.0**	53.4	52.0	49.5	47.1	**50.5**
8	RV100327	85.4	72.1	68.6	43.8	**67.5**	53.1	52.1	50.3	47.9	**50.8**
0	RV100328	88.4	74.4	61.5	56.8	**70.3**	44.4	42.4	40.9	38.5	**41.6**
10	RV100331	81.7	74.7	67.9	55.8	**70.0**	47.6	45.5	44.2	42.0	**44.8**
11	RV100334	78.7	74.7	63.5	48.5	**66.4**	50.8	49.5	47.8	44.3	**48.1**
12	RV100352	85.4	73.4	65.1	55.9	**69.9**	59.0	57.6	54.9	52.6	**56.0**
13	RV100364	79.2	72.9	67.7	47.7	**66.9**	51.1	48.9	47.7	46.3	**48.5**
14	RV100377	81.7	72.5	65.9	52.1	**68.0**	53.5	51.2	49.3	47.4	**50.4**
15	RV100382	81.1	71.7	64.8	48.8	**66.6**	52.4	49.6	46.7	45.4	**48.5**
16	RV100386	84.5	73.0	61.5	51.7	**67.7**	55.6	52.8	50.9	47.7	**51.8**
17	RV100452	80.7	72.1	64.9	55.9	**68.4**	57.4	56.4	53.7	51.0	**54.6**
18	RV100453	81.6	76.1	65.4	51.8	**68.7**	62.2	59.3	57.2	52.9	**57.9**
19	RV100458	85.0	73.7	63.8	52.5	**68.7**	56.4	54.6	52.6	49.9	**53.4**
20	RV100511	78.2	74.6	61.2	56.9	**67.7**	54.9	53.2	51.6	49.5	**52.3**
	Mean	**82.6**	**73.1**	**64.5**	**51.9**		**53**	**51.2**	**49**	**46.3**	
	P Value (A)		**0.006**					**<.001**			
	P Value (ML)		**<.001**					**<.001**			
	P Value (A x ML)		**0.12**					**<.001**			
	Lsd (A)		**3.20****					**0.66****			
	Lsd (ML)		**1.42****					**0.3****			
	Lsd (A x ML)		**NS**					**1.32****			
	CV%		**5.80**					**1.60**			

LSD- Least significant difference, LRWC- Leaf relative water content, SPAD- Chlorophyll content, **Highly significant, * Significant, NS- Not significant, 100% field capacity, 80% field capacity, 60% FC and 40% field capacity, A-accession, ML- moisture level.

4.7.3 Chemical analysis of the fruits

4.7.3.1 Total soluble solids

Accession, moisture level and accession x moisture level significantly affected the total soluble solids (Table 4.7). Reduction of water level from 100% to 60% FC significantly increased the total soluble solids (TSS) in all accessions. Total soluble solids per plant ranged from 3.90 ^{o}brix (accession RV100328) to 6.50 ^{o}brix (accession RV100331) at 100% FC and 4.33 ^{o}brix (accession RV100328) to 7.10 ^{o}brix (accession RV100331) at 60% FC. The increase in total soluble solids ranged from 0.20 ^{o}brix (accession RV100377) to 2.20 ^{o}brix (accession RV100270). Mean total soluble solids ranged from 4.67 ^{o}brix (100% FC) to 5.39 ^{o}brix (60% FC).

4.7.3.2 pH

Accession, moisture level and accession x moisture level significantly affected pH in eggplant (Table 4.7). Reduction of moisture level from 100% to 60% FC significantly decreased the pH in each accession. The pH of the accessions ranged from4.66 (accession RV100242) to 5.31 (accession GBK050572) at 100% FC and 4.40 (accession RV100169) to 4.90 (accession GBK050572) at 60% FC. The decrease in pH ranged from 1.1% (accession RV100161) to 11.2% (accession RV100458). The average pH value ranged from 4.73 (60% FC) to 4.98 (100% FC). Accessions whose pH were least affected by reduction in moisture were RV100161, RV100382, RV100453, RV100511, RV100190 and RV100263.

4.7.3.3 Titratable acidity

Accession and moisture level had significant effect on total titratable acidity but accession x moisture level had no effect on this parameter (Table 4.7). Reduction in moisture level from 100% to 60% FC increased the mean titratable acidity by 23.3%. Mean titratable acidity ranged from

0.50 (accession RV100327) to 0.9 (accessions RV100169, RV100242, RV100331, RV100352 and RV100377).

Table 4.7: Effects of moisture level (% field capacity) on Total soluble solids (ºBrix), pH and total titratable acidity of 20 African eggplant accessions

		TSS			pH			TTA		
S/no	**Accessions**	***100%**	**60%**	**Mean**	***100%**	**60%**	**Mean**	***100%**	**60%**	**Mean**
1	GBK050572	4.60	5.00	**4.80**	5.30	4.90	**5.10**	0.70	0.80	**0.80**
2	RV100161	4.00	5.50	**4.80**	4.70	4.60	**4.60**	0.60	0.70	**0.60**
3	RV100169	4.30	5.70	**5.00**	4.70	4.40	**4.50**	0.80	0.90	**0.90**
4	RV100190	4.90	5.30	**5.10**	4.60	4.40	**4.50**	0.60	0.80	**0.70**
5	RV100242	5.50	6.10	**5.80**	5.00	4.80	**4.90**	0.90	0.90	**0.90**
6	RV100263	5.00	5.50	**5.20**	5.10	4.90	**5.00**	0.50	0.80	**0.70**
7	RV100270	4.40	6.60	**5.50**	5.10	4.80	**4.90**	0.70	0.70	**0.70**
8	RV100327	4.20	4.70	**4.40**	4.90	4.70	**4.80**	0.50	0.50	**0.50**
9	RV100328	3.90	4.30	**4.10**	5.00	4.80	**4.90**	0.40	0.70	**0.60**
10	RV100331	6.50	7.10	**6.80**	5.10	4.80	**4.90**	0.70	0.90	**0.80**
11	RV100334	4.00	5.00	**4.50**	5.20	4.80	**5.00**	0.50	0.70	**0.60**
12	RV100352	4.90	5.50	**5.20**	5.10	4.90	**5.00**	0.60	0.90	**0.70**
13	RV100364	4.90	5.30	**5.10**	5.30	4.80	**5.10**	0.60	0.70	**0.70**
14	RV100377	5.50	5.70	**5.60**	5.00	4.70	**4.80**	0.80	0.90	**0.80**
15	RV100382	4.70	5.60	**5.10**	4.80	4.70	**4.80**	0.60	0.70	**0.70**
16	RV100386	4.40	4.70	**4.60**	5.00	4.70	**4.90**	0.50	0.70	**0.60**
17	RV100452	4.10	5.30	**4.70**	5.10	4.80	**5.00**	0.50	0.70	**0.60**
18	RV100453	4.60	5.40	**5.00**	5.00	4.80	**4.90**	0.60	0.60	**0.60**
19	RV100458	4.10	4.40	**4.30**	5.20	4.60	**4.90**	0.60	0.60	**0.60**
20	RV100511	4.90	5.30	**5.10**	4.70	4.50	**4.60**	0.40	0.70	**0.60**
	Mean	**4.70**	**5.40**		**5.00**	**4.70**		**0.60**	**0.70**	
	P Value (A)	**<.001**			**<.001**			**<.001**		
	P Value (ML)	**<.001**			**<.001**			**<.001**		
	P Value (A x ML)	**<.001**			**<.001**			**0.103**		
	Lsd (A)	**0.12****			**0.10****			**0.14****		
	Lsd (ML)	**0.04****			**0.03****			**0.05****		
	Lsd (A x ML)	**0.17****			**0.15****			**NS**		
	CV%	**2.1**			**1.9**			**18.7**		

LSD- Least significant difference, TSS- Total soluble solids, TTA- Titratable acidity, ** Highly significant, * Significant, NS- Not significant, *100% FC-control, 60% FC, A-accession, ML- moisture level.

4.7.3.4 β-carotene

Accession and moisture level had a significant effect on β-carotene content but accession x moisture level had no effect on this parameter (Table 4.8). Reduction of water level from 100% to 60% FC significantly increased the mean β-carotene by 29.6%. Accessions with a mean of 0.8 mg/100 g and above of β-carotene were RV100161, RV100337, RV100242, RV100327 and RV100331 while those with less than 0.3 mg/100g of β-carotene included RV100452, RV100458, RV100453, RV100364, RV100352 and RV100270. Mean β-carotene ranged from 0.21 (accession RV100352) to 0.89 mg/100g (accession RV100377).

4.7.3.5 Ascorbic acid

Accession and moisture level had significant effect on vitamin C content but accession x moisture level had no effect on this parameter (Table 4.8). Reductions of water level from 100% to 60% FC significantly increased vitamin C by 6.03%. Accessions with above 10 mg/100g of vitamin C were RV100452, RV100453, RV100386, RV100190, GBK050572, RV100161 and RV100328 while those with vitamin C content of less than 6 mg/100g included RV100169, RV100242, RV100263, RV100327 and RV100334.The mean vitamin C content ranged from 4.72 (accession RV100334) to 14.53 mg/100g (accession RV100452).

Table 4.8: Effects of moisture level (% field capacity) on β-carotene (mg/100g) and Ascorbic acid (mg/100g) of 20 African eggplant accessions

		β-Carotene			Vitamin C		
S/no	**Accessions**	***100%**	**60%**	**Mean**	***100%**	**60%**	**Mean**
1	GBK050572	0.20	0.30	**0.25**	12.84	13.53	**13.18**
2	RV100161	0.86	0.89	**0.88**	9.98	10.35	**10.17**
3	RV100169	0.68	0.87	**0.78**	4.80	5.05	**4.92**
4	RV100190	0.49	0.71	**0.60**	14.06	14.45	**14.26**
5	RV100242	0.71	0.89	**0.80**	5.19	5.83	**5.51**
6	RV100263	0.27	0.36	**0.31**	5.39	5.58	**5.49**
7	RV100270	0.20	0.31	**0.25**	7.95	8.41	**8.18**
8	RV100327	0.81	0.92	**0.87**	4.78	5.66	**5.22**
0	RV100328	0.21	0.27	**0.24**	9.82	10.37	**10.10**
10	RV100331	0.65	0.95	**0.80**	5.42	5.62	**5.52**
11	RV100334	0.43	0.49	**0.46**	4.55	4.90	**4.72**
12	RV100352	0.14	0.29	**0.21**	7.03	7.25	**7.14**
13	RV100364	0.16	0.37	**0.27**	9.72	10.14	**9.93**
14	RV100377	0.85	0.94	**0.89**	6.72	7.05	**6.89**
15	RV100382	0.25	0.28	**0.27**	5.81	6.30	**6.06**
16	RV100386	0.34	0.46	**0.40**	12.98	13.29	**13.14**
17	RV100452	0.24	0.28	**0.26**	13.82	15.25	**14.53**
18	RV100453	0.37	0.63	**0.50**	13.35	14.09	**13.72**
19	RV100458	0.17	0.29	**0.23**	5.31	5.82	**5.57**
20	RV100511	0.72	0.82	**0.77**	6.03	6.62	**6.33**
	Mean	**0.44**	**0.57**		**8.28**	**8.78**	
	P Value (A)		**<.001**			**<.001**	
	P Value (ML)		**<.001**			**<.001**	
	P Value (A x ML)		**0.138**			**0.994**	
	Lsd (A)		**0.092****			**0.689****	
	Lsd (ML)		**0.029****			**0.218****	
	Lsd (A x ML)		**NS**			**NS**	
	CV%		**16.00**			**7.00**	

LSD- Least significant difference, ** Highly significant, * Significant, NS- Not significant, *100% FC-control, 60% FC, A-accession, MS- moisture level.

4.7.3.6 Chemical analysis

4.7.3.6.1 Magnesium

Accession and moisture level had significant effect on Mg but accession x moisture level had no effect on this parameter (Table 4.9). Reduction of water level from 100% to 60% FC significantly decreased Mg content by 42.9%. Accessions with higher than 0.2 mg/100g Mg included RV100511, RV100331 and RV100382 while accessions with less than 0.13 mg/100g were RV100169, RV100328 and RV100352. Mean Mg content ranged from 0.11 (accession RV100352) to 0.23 mg/100 g (accession RV100270 and RV100511).

4.7.3.6.2 Calcium

Accession and moisture level had significant effect on Ca but accession x moisture level had no effect on this parameter (Table 4.9). Reduction of water level from 100% to 60% FC significantly decreased Ca content by 44.3%. Accessions with 0.40 mg/100g and above Ca included RV100328, RV100364 and RV100382 while accession with less than 0.20 mg/100g Ca was RV100263. Mean Ca content ranged from 0.19 (accession RV100263) to 0.48 mg/100 g (accession RV100382).

Table 4.9: Effects of moisture level (% field capacity) on magnesium (mg/100g) and calcium (mg/100g) content of 20 African eggplant accessions

		Magnesium			Calcium		
S/no	**Accessions**	**100%**	**60%**	**Mean**	**100%**	**60%**	**Mean**
1	GBK050572	0.27	0.15	**0.21**	0.43	0.27	**0.35**
2	RV100161	0.25	0.16	**0.20**	0.39	0.23	**0.31**
3	RV100169	0.23	0.11	**0.17**	0.45	0.26	**0.36**
4	RV100190	0.22	0.15	**0.18**	0.31	0.16	**0.24**
5	RV100242	0.23	0.12	**0.17**	0.43	0.23	**0.33**
6	RV100263	0.21	0.13	**0.17**	0.25	0.13	**0.19**
7	RV100270	0.27	0.18	**0.23**	0.32	0.15	**0.23**
8	RV100327	0.27	0.14	**0.21**	0.3	0.11	**0.20**
0	RV100328	0.24	0.11	**0.17**	0.52	0.3	**0.41**
10	RV100331	0.23	0.13	**0.18**	0.34	0.15	**0.25**
11	RV100334	0.23	0.11	**0.17**	0.45	0.23	**0.34**
12	RV100352	0.15	0.08	**0.11**	0.43	0.26	**0.35**
13	RV100364	0.23	0.12	**0.17**	0.53	0.25	**0.39**
14	RV100377	0.2	0.11	**0.15**	0.3	0.13	**0.21**
15	RV100382	0.27	0.15	**0.21**	0.56	0.41	**0.48**
16	RV100386	0.24	0.15	**0.19**	0.37	0.21	**0.29**
17	RV100452	0.23	0.11	**0.17**	0.38	0.14	**0.26**
18	RV100453	0.21	0.13	**0.17**	0.47	0.33	**0.40**
19	RV100458	0.22	0.11	**0.17**	0.48	0.23	**0.35**
20	RV100511	0.25	0.2	**0.23**	0.42	0.34	**0.38**
	Mean	**0.23**	**0.13**		**0.41**	**0.23**	
	P Value (A)	**<.001**			**<.001**		
	P Value (ML)	**<.001**			**<.001**		
	P Value (A x ML)	**0.911**			**0.288**		
	Lsd (A)	**0.043****			**0.062****		
	Lsd (ML)	**0.013****			**0.020****		
	Lsd (A x ML)	**NS**			**NS**		
	CV%	**20.4**			**17.1**		

LSD- Least significant difference, ** Highly significant, * Significant, NS- Not significant, *100% FC-control, 60% FC, A-accession, ML- moisture level.

4.7.3.6.3 Iron

Accession and moisture level had significant effect on Fe content but accession x moisture level had no effect on this parameter (Table 4.10). Reduction of water level from 100% to 60% FC significantly decreased Fe content by 47.3%. Eight accessions had higher than 1.00 mg/100g of Fe content. Iron content ranged from 0.75 (accession RV100452) to 1.56 mg/100 g (accession RV100263).

4.7.3.6.4 Zinc

Accession, moisture level and accession x moisture level significantly affected Zn content in eggplant (Table 4.10). Reduction of water level from 100% to 60% FC significantly decreased mean Zn content by 18.9%. The value of Zn content per accession ranged from 0.44 mg/100 g (Accession RV100169) to 0.79 mg/100 g (accession RV100270) at 100% FC and 0.34 mg/100g (accession RV100352) to 0.52 mg/100g (accession RV100270) at 60% FC.

Table 4.10: Effects of moisture level (% field capacity) on Iron (mg/100 g) and Zinc (mg/100 g) content of 20 African eggplant accessions

		Iron			Zinc		
S/no	**Accessions**	***100%**	**60%**	**Mean**	***100%**	**60%**	**Mean**
1	GBK050572	1.48	0.65	**1.07**	0.52	0.42	**0.47**
2	RV100161	1.46	0.88	**1.17**	0.55	0.50	**0.53**
3	RV100169	1.28	0.67	**0.98**	0.44	0.36	**0.40**
4	RV100190	1.03	0.59	**0.81**	0.52	0.43	**0.48**
5	RV100242	1.31	0.70	**1.01**	0.54	0.39	**0.46**
6	RV100263	1.78	1.34	**1.56**	0.55	0.46	**0.50**
7	RV100270	1.55	0.74	**1.15**	0.79	0.52	**0.65**
8	RV100327	1.13	0.55	**0.84**	0.54	0.40	**0.47**
0	RV100328	1.05	0.61	**0.83**	0.53	0.40	**0.46**
10	RV100331	1.50	0.76	**1.13**	0.63	0.50	**0.57**
11	RV100334	1.28	0.40	**0.84**	0.56	0.39	**0.47**
12	RV100352	1.20	0.53	**0.86**	0.45	0.34	**0.39**
13	RV100364	1.10	0.66	**0.88**	0.54	0.40	**0.47**
14	RV100377	1.59	1.01	**1.30**	0.43	0.35	**0.39**
15	RV100382	1.30	0.60	**0.95**	0.46	0.41	**0.44**
16	RV100386	1.17	0.58	**0.88**	0.48	0.40	**0.44**
17	RV100452	1.03	0.47	**0.75**	0.63	0.43	**0.53**
18	RV100453	1.35	0.92	**1.14**	0.50	0.45	**0.48**
19	RV100458	1.33	0.51	**0.92**	0.56	0.43	**0.49**
20	RV100511	1.17	0.62	**0.89**	0.52	0.47	**0.50**
	Mean	**1.31**	**0.69**		**0.53**	**0.43**	
	P Value (A)	**<.001**			**<.001**		
	P Value (ML)	**<.001**			**<.001**		
	P Value (A x ML)	**0.956**			**<.001**		
	Lsd (A)	**0.290****			**0.055****		
	Lsd (ML)	**0.090****			**0.017****		
	Lsd (A x ML)	**NS**			**0.078****		
	CV%	**24.90**			**10.00**		

LSD- Least significant difference, ** Highly significant, * Significant, NS- Not significant, 100% FC-control, 60% FC.A-accession, ML- moisture level.

4.7.3.7 Correlation coefficient among the quantitative, physiological and nutritional quality traits

African eggplant accessions showed a highly significant positive correlation between fruit yield with fruit weight and single leaf area (Table 4.11). Calcium content was highly significant and positively correlated to leaf relative water content and chlorophyll content. Fruit yield was positively correlated to β-carotene, iron, LRWC and vitamin C while it was negatively correlated to chlorophyll content. Vitamin C was significant and positively correlated to β-carotene.

Table 4.11: Correlation coefficient table for the quantitative traits, physiological parameters and nutritional quality components recorded for accessions grown in water stressed and non-water stressed conditions

Traits	β-Car	FW	Fe	LRWC	SLA	SPAD	Vit C	F Y	Ca
β-carotene	-								
Fruit weight	0.06	-							
Iron	0.26*	0.11	-						
LRWC	0.18	0.17	0.68**	-					
SLA	0.05	0.34**	0.31**	0.38**	-				
SPAD	-0.13	-0.07	0.39**	0.41**	0.23	-			
Vitamin C	0.25*	-0.05	-0.04	0.10	-0.03	0.001	-		
Fruit yield	0.06	0.92**	0.11	0.17	0.34**	-0.07	0.05	-	
Calcium	-0.01	0.03	0.42**	0.63**	0.27*	0.35**	0.09	0.03	-

β-Car- β-Carotene, FW- Fruit weight, Fe-Iron, LRWC- Leaf relative water content, SLA- Single leaf area, SPAD- Chlorophyll content, Vit C- Vitamin C, FY- Fruit yield, Ca- Calcium

4.8 Discussion

Reduction in moisture level significantly decreased plant height, stem girth and single leaf area content. These results are in agreement with those of Kirnak *et al*. (2001) who reported that water stress reduced vegetative growth of eggplant. This may be attributed to the fact that water stress alters many physiological and metabolic processes in plants (Gunes *et al.,* 2006). Variation was noticed among the accessions ($P<0.05$) in stem girth. Plant height decreased by 20.1% with

reduction in moisture level which was in agreement with the findings of Aguyoh *et al.* (2013) who noted that plant height in tomato plant reduce by 22.3% with reduction in moisture level. Single leaf area decreased by 18.1% with reduction in moisture level. These findings are corroborated by Lopez *et al*. (1997) who noted that leaf area of pigeon pea decreased by 22.5% with reduction in moisture level.

Stem girth decreased with increase in drought stress thus interfering with the growth habit of the eggplant. Stem girth is an important trait that determines lodging in plants (Gunes *et al.*, 2006). Bradford and Hsiao (1982) found out that stem girth and plant growth may be inhibited at low water availability despite complete maintenance of turgor in the growing regions as a result of osmotic adjustment. Stem girth decreased by 15.3% with reduction in moisture level. Aguyoh *et al.* (2013) also reported a decrease in stem girth of tomato by 11% with decrease in moisture level.

Fruit weight and yield declined significantly with the reduction in moisture level. Previous studies demonstrated that soil moisture deficit significantly reduced fruit weight, number of fruits per plant and fruit yield (Abd El-Aal *et al.*, 2008; Birhanu and Tilahun, 2010). Accessions that were superior in fruit yield trait included RV100452, RV100327 and GBK050572. Mean fruit yield varied from 1.6 t/ha in accession RV100453 to 39.3 t/ha in accession RV100452, Thus demonstrating huge variability in the fruit traits. Aguyoh *et al.* (2013) reported that fruit yield of tomato plants decreased from 69.5 t/ha to 25 t/ha with the decrease in water level.

Mean stomata conductance decreased significantly with a reduction in moisture level. Yazdarpanah *et al.* (2011) reported that stomatal conductance was significantly affected by reduction in moisture level. However, the reduction in moisture effect on stomatal conductance was dependent on the eggplant accession. Moisture reduction had no effect on accession

RV100328. Mean stomatal conductance varied from 168.6 mmol $m^{-2}s^{-1}$ in accession RV100263 to 415.6 mmol $m^{-2}s^{-1}$ in accession RV100458. Aguyoh *et al.* (2013) confirmed that decrease in moisture level leads to a decrease in stomata conductance in tomato due to partial stomatal closure. Aguyoh *et al.* (2013) observed that the mean stomata conductance of tomato plants ranged from 94.0 mmol $m^{-2}s^{-1}$ in water stressed plants to 227.5 mmol $m^{-2}s^{-1}$ in well water plants.

Eggplant canopy temperature increased with reduction of moisture level from 100% FC to 40% FC by 19.7%. Accessions grown in 100% FC were cooler due to enough water loss by transpiration unlike the crops grown in a water stressed environment which had low stomatal conductance leading to high canopy temperature. Kirnak *et al.* (2001) reported that canopy temperature might also be dependent on climatic parameters and internal plant water status. High crop canopy temperature in water-stressed plants may also be related to decreased transpiration rate and leaf relative water content (Yazdarpanah *et al*., 2011; Aguyoh *et al.,* 2013) observed in the current study. Mean canopy temperature varied from 24.1^0C in accession RV100382 to 29.9^0C in accession RV100377. Canopy temperature response to reduction in moisture level was dependent on the accession. Dejonge *et al.* (2015) made similar observations in maize that water stress significantly increased canopy temperature to 29^0C.

Leaf relative water content decreased with increasing drought stress. This finding is in agreement with that of Kirnak *et al.* (2001) who established that relative water content of tomato decreased with reducing moisture level. Amira (2014) also found similar results in soybean leaves. Leaf relative water content varied with eggplant accession from 63.5% in accession RV100242 to 70.3% in accession RV100328. Aguyoh *et al.* (2013) made a similar observation on tomato that leaf relative water content ranged from 87.7% in well-watered plants to 66.2% in water stressed tomato plants.

It was evident from this study that water stress decreased chlorophyll content in the African eggplants. The decrease in chlorophyll content under drought is a commonly observed phenomenon (Kirnak *et al*., 2001; Kumar *et al*., 2011; Heba and Samia, 2014; Amira, 2014). Decrease in chlorophyll content under drought might be attributed to reduced synthesis of the main chlorophyll pigment complexes encoded by the *cab* gene family (Nikolaeva *et al.,* 2010; Amira, 2014). The impact of water stress on chlorophyll content was dependent on the accession. SPAD readings varied with eggplant accession from 41.6 in accession RV100328 to 57.9 in accession RV100453. These studies are corroborated by Aguyoh *et al.* (2013) who recorded SPAD readings of 41.9 in water stressed tomato plants and 61.5 in well water tomato plants.

Total soluble solids increased significantly as the moisture level decreased from 100% FC to 60% FC. The reduction of total soluble solids with increase in water level can be attributed to the higher water uptake by the plants, leading to dilution of the concentration of TSS. A similar observation was made on cantaloupe (*Cucumis melo* L.) by Mahmoud *et al*. (2013). The results obtained by different researchers (Fabeiro *et al.,* 2002; Ribas *et al.,* 2003; Kirnak *et al.,* 2005; Mahmoud *et al.,* 2013) show that fruit sugar content is affected positively by water deficit. The effect of water stress on total soluble solids varied with the accession type. Accessions that were superior in total soluble solids were RV100242 (5.78 ^{o}brix) and RV100331 (6.80 ^{o}brix). Mitchell *et al.* (1991) made similar observation that total soluble solids range from 4.58 ^{o}brix in well water tomatoes to 5.88 ^{o}brix in tomatoes under low moisture level.

Reduced moisture content increased acidity in African eggplant fruits. The impact of moisture stress on fruit acidity was dependent on the accession type. Titratable acidity ranged from a mean of 0.5 in accession RV100327 to 0.8 in accession GBK050572. Mitchell *et al.* (1991) made similar observation that titratable acidity range from 0.28in well water tomatoes to 0.34 in tomatoes under

low moisture level. Abdel-Razzak *et al*. (2013) reported that a decrease in moisture level increased titratable acidity in cherry tomato.

Reduction in moisture level led to a significant increase in β-carotene and vitamin C in eggplant fruit. The β-carotene increased by 22.8% with reduction in moisture level from 100% FC to 60% FC. Favati *et al.* (2009) observed that compared to well irrigated accessions β-carotene concentration was higher in less irrigated tomatoes. Helyes *et al*. (2014) also reported that β-carotene increased with increase in water stress in tomatoes. Mean β-carotene content varied from 0.21 mg/100g in accession RV100352 to 0.89 mg/100g in accession RV100337. Favati *et al.* (2009) observed that β-carotene concentration in tomato varied from 1.16 mg/100g to 3.70 mg/100g when subjected to varying moisture levels.

Vitamin C increased by a mean of 5.7% when moisture level reduced from 100% FC to 60% FC. These results are in agreement with the findings of Nahar (2002) who reported that ascorbic acid concentration in fruit increased with increase in water stress in tomatoes. There was a positive correlation between β-carotene and vitamin C contents. Under water stress conditions, ascorbic acid assist in the counteraction of the adverse effects of water stress, stabilization and protection of the photosynthetic pigments and the photosynthetic apparatus from oxidization (Khan *et al*., 2011). Accessions that were superior in vitamin C were RV100452 (14.53 mg/100g) and RV100190 (14.26 mg/100g). Mean vitamin C content ranged from 4.72 mg/100g in accession RV100334 to 14.53 mg/100g in accession RV100453 which is in agreement with the findings of Mahmoud *et al*. (2012) who found the mean of vitamin C content varying from 28.1 mg/100g to 32.4 mg/100g under different moisture levels in tomato. It is clear that vitamin C is high in tomatoes as compared to African eggplants.

Decrease in moisture level significantly decreased magnesium, calcium, iron and zinc content by 43.5%, 43.9%, 47.3% and 18.9% respectively. These findings are in agreement with those of Agbemafle *et al.* (2015) who observed that a decrease in moisture level led to reduction in Mg, Ca, Fe and Zn content in tomato by 50%, 66.7%, 44.4% and 41.2% respectively. Most mineral nutrients are dependent on soil moisture to move through the soil layers and be taken up by the plants through the roots (Taiz and Zeiger 2006; Silva *et al.,* 2009). Current findings are in agreement with previous studies by Nahar (2002) who reported diminishing concentrations of Fe, Zn, Ca and Mg with increasing water stress in tomato plants. Having enough water at field capacity enables effective uptake of nutrients into the plant which translates to high mineral content in well water eggplant fruits. Fruit yield was positively correlated to fruit weight, single leaf area, β-carotene, vitamin C, leaf relative water content and negatively correlated to chlorophyll content.

4.9 Conclusion

Water stress significantly decreased growth, yield, stomatal conductance, leaf relative water content, chlorophyll greenness index, pH value, magnesium, calcium, iron and zinc. It however, significantly increased canopy temperature, β-carotene, vitamin C, titratable acidity and total soluble solids in the fruits. The response to water stress in most of the growth, yield, physiological and nutritional quality components was dependent on the accessions.

CHAPTER 5: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

The study showed a wide diversity among the 72 accessions for all the 17 qualitative and quantitative traits evaluated. Upright, intermediate and prostrate growth habits were observed among the accessions. The upright trait is important for good vigor which enables the plants to grow to the height required in a production greenhouse. Most of the accessions had white flowers, a few accessions having pale violet flowers, light violet flowers and bluish violet flowers. The flower pigments (examples anthocyanins, aurones, chalcones, flavonols, carotenes and proanthocyanidins) are responsible for a variety of colours in vegetables.

Most of the accessions had leaf hairs and leaf prickles. These two traits are important for classification of African eggplant into different species and different origins. Accessions growing in the field appeared to have more leaf hairs and leaf prickles than those in the greenhouse. These traits are important in preventing insect attack and consumption by herbivores due to the irritability to the palate and stiffness. Although most of the accessions evaluated had leaf hairs and leaf prickles, most farmers prefer non-prickled leaf types for ease of harvest as stated by Naujeer (2009). This suggests the need for breeders to breed African eggplants that have no leaf and stem prickles for ease of harvest by farmers. Leaf prickles, flower colour and fruit breadth showed high diversity indices.

Accessions used in cluster analysis were grouped based on their species and origin. Both field and greenhouse grown accessions were grouped into two clusters. Cluster I of field grown accessions grouped the accessions from different origins and species that are closely related. Cluster II of the field grown accessions were mostly made up of small sized fruits. Sub cluster ‘c’ was made up of most of the S. *anguivi* accessions, some *Solanum* species accessions and the only S. *macrocarpon*

accession in the study. Sub cluster ‘d’ was mostly made of accessions from *solanum aethiopicum* species and originating from Mali. Cluster I of greenhouse grown accessions grouped the accessions from different origins, species, flower colour and growth habit that are closely related. Cluster II of the greenhouse grown accessions were made up of leaf prickled and varying fruit sized accessions. Sub cluster ‘z’ was made up of most of the S. *anguivi*, some *solanum* species and the only S. *macrocarpon* accession in the study. Sub clusters ‘y and p’ were made of accessions from *Solanum aethiopicum* species.

Principal component analysis identified six key traits namely leaf hairs, leaf prickles, fruit position, fruit shape, fruit breadth and flower colour which could help in characterization of eggplant accessions. Selection and characterization is important for storage of the accessions in gene banks and easy accessibility of the accessions by farmers.

Reduction in moisture level leads to reduced photosynthetic rate which decreases vegetative growth significantly decreasing fruit weight and yield per hectare of eggplant accessions. Reduction in moisture level significantly decreased leaf relative water content, chlorophyll content and stomatal conductance while increasing the canopy temperature. Lowering moisture level in the soil decreases the water absorption rate of accessions in the soil which translates to low stomatal conductance leading to increased canopy temperature.

Reduction in moisture level led to an increase in titratable acidity of the African eggplant fruit. Accessions growing under water stress conditions had fruits with reduced water content leading to increased acidity.

The β-carotene and vitamin C increased with reduction in moisture level. Increase in moisture level may have led to high moisture content in the fruits, thus inducing a dilution effect on β-

carotene and vitamin C concentration. In contrast, water stress led to accumulation of vitamin C and β-carotene concentration in eggplant fruit. Water stress reduced Mg, Ca, Fe and Zn content. The water at field capacity (100% FC) may have enabled effective uptake of nutrients into the plant which translates to high mineral content in well water eggplant fruits, while lower field capacity (60% FC) may have reduced mineral intake.

5.2 Conclusions

Morphological and agronomic traits of African eggplant accessions varied significantly between different species, indicating the potential for genetic improvement of the crop through selection and cross breeding. Reduction in water level significantly decreased growth, stomatal conductance, leaf relative water content, chlorophyll content, pH value, magnesium, calcium, iron and zinc. It, however, significantly increased canopy temperature, β-carotene, vitamin C, titratable acidity and total soluble solids in the fruits. This study demonstrated that the growth, physiological parameters, yield and nutritional quality of African eggplant accessions are dependent on the genotype and environment.

5.3 Recommendations

1. The present study revealed wide morphological and agronomic diversity in African eggplant accessions. It is advisable for the breeders to take advantage of this rich natural gene pool for hybridization and introgression of desirable genes into the cultivated varieties.

2. This study also recommends that molecular markers such as simple sequencer Repeats (SSRs) be used to supplement this work by identifying the polymorphism that is not affected by environmental conditions.

3. Since the current study covered a few accessions it is advisable that a similar study covering a wider range of accessions be conducted in a broad range of environments. In addition studies on

genetic erosion intensity and ecological mapping of population diversity structure of eggplant landraces and their related species should be considered.

4. Accessions GBK050572, RV100331, RV100351, RV100452 and RV100190 are recommended for breeding drought tolerant eggplant accessions which are high in titratable acidity, total soluble solids, β-carotene and vitamin C content.

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APPENDICES

Appendix 1: Weather conditions at Kabete field station between May 2014to May 2015 cropping season.

	Temperature(°C)		Relative humidity (%)	Rainfall (mm)
Months	**Mean max**	**Mean min**	**Mean**	**Total**
May	23.5	14.8	55.1	72.8
June	23.3	14.1	64.1	101.5
July	21.6	12.5	61.0	10
August	N/A	12.4	54.3	28.9
September	22.3	12.2	52.0	23.9
October	N/A	14.5	51.7	136.2
November	N/A	14.4	58.6	95.5
December	N/A	13.8	55.2	88.6
January	25.7	12.8	41.1	27.7
February	N/A	13.6	40.8	50.8
March	14.2	N/A	40.4	30.1
April	N/A	15.3	55.5	323.9
May	N/A	14.0	63.6	298.3

Source: Kenya Meteorological Department, Kabete Agro-met Station (June 2015).

Appendix 2: Chemical characteristics of sampled greenhouse soil.

Fertility Results	**Value**
Soil pH	7.04
Total nitrogen (%)	0.29
Organic carbon (%)	2.87
Phosphorous (ppm)	149
Potassium me%	0.4
Calcium me%	11.7
Magnesium me%	8.2
Manganese me %	0.78
Copper ppm	8.53
Iron ppm	82.3
Zinc ppm	31.3
Sodium me%	0.4
Electrical conductance mS/cm	0.62

Appendix 3: Chemical characteristics of sampled field soil.

Fertility Results	**Value**
Soil pH	5.78
Total nitrogen (%)	0.22
Organic carbon (%)	2.22
Phosphorous (ppm)	45
Potassium me%	1.59
Calcium me%	6.3
Magnesium me%	6.49
Manganese me %	0.7
Copper ppm	3.58
Iron ppm	60.5
Zinc ppm	27.5
Sodium me%	0.24

Appendix 4: Analysis of variance (ANOVA) table for the days to flowering for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	52.12	26.06	3.84	
Accession	71	1272.87	17.928	2.64	<.001**
Residual	358	964.546	6.793		
Total	431	2289.537			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 5: Analysis of variance (ANOVA) table for the SPAD Value for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	459.415	229.707	43.06	
Accession	71	8294.273	116.821	21.9	<.001**
Residual	358	757.472	5.334		
Total	431	9511.16			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 6: Analysis of variance (ANOVA) table for the Plant height for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	8.13E-01	4.07E-01	1.53	
Accession	71	1.30E+05	1.84E+03	6907.23	<.001**
Residual	358	8.70E+01	4.20E-01		
Total	431	1.30E+05			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 7: Analysis of variance (ANOVA) table for the leaf blade length for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	5.2824	2.6412	9.15	
Accession	71	7108.5373	104.1077	360.6	<.001**
Residual	358	82.5709	0.2887		
Total	431	7196.3907			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 8: Analysis of variance (ANOVA) table for the leaf blade width for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.8429	0.4215	0.78	
Accession	71	4113.4615	67.9171	125.26	<.001**
Residual	358	189.6087	0.5422		
Total	431	4303.9131			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 9: Analysis of variance (ANOVA) table for the fruit length for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	4.952	2.476	4.52	
Accession	71	3076.595	43.3323	83.29	0.02*
Residual	358	214.0197	2.8171		
Total	431	3295.5666			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 10: Analysis of variance (ANOVA) table for the fruit breadth for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	11.705	5.8525	14.46	
Accession	71	17.9415	0.2527	0.62	0.991ns
Residual	358	1051.8496	44.991		
Total	431	1081.4961			

***** = significant, ****** = highly significant, ns = not significant, F pr = F probability value

Appendix 11: Analysis of variance (ANOVA) table for the fruit weight for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	29.592	14.796	3.82	
Accession	71	344.581	4.853	1.25	0.102ns
Residual	358	283409.767	4032.182		
Total	431	283783.939			

***** = significant, ****** = highly significant, ns = not significant, F pr = F probability value

Appendix 12: Analysis of variance (ANOVA) table for the number of fruits per plant for the field grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	97.04	48.52	1.64	
Accession	71	2021.9	28.48	0.96	0.57ns
Residual	358	1725372.46	24239.25		
Total	431	1727491.4			

***** = significant, ****** = highly significant, ns = not significant, F pr = F probability value

Appendix 13: Analysis of variance (ANOVA) table for the days to flowering for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	60.454	30.227	10.46	
Accession	71	1232.87	17.364	6.01	0.045*
Residual	142	410.213	2.889		
Total	215	1703.537			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 14: Analysis of variance (ANOVA) table for the SPAD Value for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	230.815	115.408	14.28	
Accession	71	6672.95	93.985	11.63	<.001**
Residual	142	1147.452	8.081		
Total	215	8051.217			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 15: Analysis of variance (ANOVA) table for the plant height for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	399.207	199.603	29.7	
Accession	71	60430.486	851.134	126.64	<.001**
Residual	142	954.34	6.721		
Total	215	61784.033			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 16: Analysis of variance (ANOVA) table for the leaf blade length for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	57.3501	28.675	40.64	
Accession	71	2985.3533	42.0472	59.6	<.001**
Residual	142	100.1832	0.7055		
Total	215	3142.8866			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 17: Analysis of variance (ANOVA) table for the leaf blade width for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	71.7215	35.8607	142.11	
Accession	71	1960.6793	27.6152	109.44	<.001**
Residual	142	35.8319	0.2523		
Total	215	2068.2326			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 18: Analysis of variance (ANOVA) table for the fruit length for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	43.334	21.667	49.96	
Accession	71	1474.4348	20.7667	47.89	<.001**
Residual	142	61.5794	0.4337		
Total	215	1579.3481			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 19: Analysis of variance (ANOVA) table for the fruit breadth for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	44.0711	22.0356	82.44	
Accession	71	406.6117	5.7269	21.43	<.001**
Residual	142	37.9556	0.2673		
Total	215	488.6383			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 20: Analysis of variance (ANOVA) table for the fruit weight for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	180.031	90.016	17.19	
Accession	71	128787.512	1813.909	346.3	<.001**
Residual	142	743.782	5.238		
Total	215	129711.325			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 21: Analysis of variance (ANOVA) table for the number of fruits per plant for the greenhouse grown accessions during the seasons of 2014 and 2015.

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	327.17	163.585	17.33	
Accession	71	772467.33	10879.822	1152.34	<.001**
Residual	142	1340.69	9.441		
Total	215	774135.19			

***** = significant, ****** = highly significant, F pr = F probability value

Appendix 22: Analysis of variance (ANOVA) table for the plant height for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	95.8	47.9	21.58	
Acc. Code	19	30404.097	1600.216	720.98	<.001
Stress level	3	3792.801	1264.267	569.62	<.001
Acc. Code*SL	57	593.359	10.41	4.69	<.001
Residual	158	350.68	2.219		
Total	239	35236.737			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 23: Analysis of variance (ANOVA) table for the single leaf area for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	16.8136	8.4068	15.92	
Acc. Code	19	3493.2362	183.8545	348.13	<.001
Stress level	3	650.7993	216.9331	410.77	<.001
Acc. Code*SL	57	119.7075	2.1001	3.98	<.001
Residual	158	83.4418	0.5281		
Total	239	4363.9984			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 24: Analysis of variance (ANOVA) table for the fruit weight for the accessions grown under water stress **and non-water stress** conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	26.11	13.055	11.08	
Acc. Code	19	112032.773	5896.462	5005.49	<.001
Stress level	3	1177.62	392.54	333.23	<.001
Acc. Code*SL	57	421.637	7.397	6.28	<.001
Residual	158	186.124	1.178		
Total	239	113844.263			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 25: Analysis of variance (ANOVA) table for the stem girth for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.03925	0.01963	0.26	
Acc. Code	19	20.8435	1.09703	14.75	<.001
Stress level	3	53.0415	17.6805	237.8	<.001
Acc. Code*SL	57	7.18683	0.12608	1.7	0.006
Residual	158	11.74742	0.07435		
Total	239	92.8585			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 26: Analysis of variance (ANOVA) table for stomatal conductance for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	468.8	234.4	0.61	
Acc. Code	19	1244895.2	65520.8	170.92	<.001
Stress level	3	1797105.6	599035.2	1562.67	<.001
Acc. Code*SL	57	330678.7	5801.4	15.13	<.001
Residual	158	60568	383.3		
Total	239	3433716.3			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 27: Analysis of variance (ANOVA) table for canopy temperature for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.3409	0.1705	0.3	
Acc. Code	19	482.5764	25.3988	45.04	<.001
Stress level	3	748.7683	249.5894	442.64	<.001
Acc. Code*SL	57	69.7623	1.2239	2.17	<.001
Residual	158	89.0908	0.5639		
Total	239	1390.5388			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 28: Analysis of variance (ANOVA) table for LRWC% for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	334.63	167.32	10.8	
Acc. Code	19	626.69	32.98	2.13	0.006
Stress level	3	30568.8	10189.6	657.6	<.001
Acc. Code*SL	57	1125.07	19.74	1.27	0.123
Residual	158	2448.24	15.5		
Total	239	35103.44			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 29: Analysis of variance (ANOVA) table for chlorophyll content for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.079	0.0395	0.06	
Acc. Code	19	3973.6705	209.1406	312.92	<.001
Stress level	3	1516.9467	505.6489	756.56	<.001
Acc. Code*SL	57	95.7539	1.6799	2.51	<.001
Residual	158	105.5993	0.6684		
Total	239	5692.0495			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 30: Analysis of variance (ANOVA) table for total soluble solids for the accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.41618	0.20809	18.68	
Acc. Code	19	41.31414	2.17443	195.18	<.001
Stress level	1	15.6891	15.6891	1408.31	<.001
Acc. Code*SL	19	7.27238	0.38276	34.36	<.001
Residual	78	0.86895	0.01114		
Total	119	65.56076			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 31: Analysis of variance (ANOVA) table for pH for accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.374107	0.187053	22.86	
Acc. Code	19	3.276216	0.172432	21.07	<.001
Stress level	1	1.827801	1.827801	223.34	<.001
Acc. Code*SL	19	0.497216	0.026169	3.2	<.001
Residual	78	0.63836	0.008184		
Total	119	6.613699			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 32: Analysis of variance (ANOVA) table for total titratable acidity for accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.0172	0.0086	0.55	
Acc. Code	19	1.33458	0.07024	4.49	<.001
Stress level	1	0.51992	0.51992	33.22	<.001
Acc. Code*SL	19	0.45079	0.02373	1.52	0.103
Residual	78	1.22072	0.01565		
Total	119	3.54321			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 33: Analysis of variance (ANOVA) table forβ-carotene for accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.049254	0.024627	3.83	
Acc. Code	19	8.005103	0.421321	65.51	<.001
Stress level	1	0.498948	0.498948	77.58	<.001
Acc. Code*SL	19	0.174535	0.009186	1.43	0.138
Residual	78	0.501648	0.006431		
Total	119	9.229488			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 34: Analysis of variance (ANOVA) table for vitamin Cfor accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	7.7352	3.8676	10.76	
Acc. Code	19	1416.4567	74.5504	207.49	<.001
Stress level	1	7.5191	7.5191	20.93	<.001
Acc. Code*SL	19	2.3717	0.1248	0.35	0.994
Residual	78	28.0257	0.3593		
Total	119	1462.1084			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 35: Analysis of variance (ANOVA) table for magnesium for accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.00308	0.00154	1.12	
Acc. Code	19	0.084688	0.004457	3.24	<.001
Stress level	1	0.289145	0.289145	210.28	<.001
Acc. Code*SL	19	0.015124	0.000796	0.58	0.911
Residual	78	0.107255	0.001375		
Total	119	0.499292			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 36: Analysis of variance (ANOVA) table for calcium for accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.148526	0.074263	25.51	
Acc. Code	19	0.716696	0.037721	12.96	<.001
Stress level	1	0.979962	0.979962	336.66	<.001
Acc. Code*SL	19	0.065811	0.003464	1.19	0.288
Residual	78	0.227042	0.002911		
Total	119	2.138037			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 37: Analysis of variance (ANOVA) table for iron for accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.28972	0.14486	2.35	
Acc. Code	19	4.46298	0.23489	3.81	<.001
Stress level	1	11.38377	11.38377	184.63	<.001
Acc. Code*SL	19	0.58457	0.03077	0.5	0.956
Residual	78	4.80915	0.06166		
Total	119	21.53018			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level

Appendix 38: Analysis of variance (ANOVA) table for zinc for accessions grown under water stress and non-water stress conditions

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep	2	0.031437	0.015719	6.81	
Acc. Code	19	0.419607	0.022085	9.56	<.001
Stress level	1	0.356554	0.356554	154.4	<.001
Acc. Code*SL	19	0.12167	0.006404	2.77	<.001
Residual	78	0.180125	0.002309		
Total	119	1.109393			

***** = significant, ****** = highly significant, F pr = F probability value, SL-stress level