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AGRO-MORPHOLOGICAL AND NUTRITIONAL CHARACTERIZATION OF HORNED MELON ACCESSIONS FROM SELECTED AGRO-ECOLOGICAL ZONES IN KENYA

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

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DEDICATION

This thesis is dedicated to my family for their unwavering support, patience and true love during my study years.

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LIST OF ABBREVIATIONS /ACRONYMS

AEZ	-	Agro-ecological Zone
ANOVA	-	Analysis of variance
ASL	-	Above sea level
CL	-	Coastal Lowlands
DNA	-	Deoxyribonucleic acid
HCDA	-	Horticultural Crops Development Authority
F1	-	First factor in PCA
F2	-	Second factor in PCA
F3	-	Third factor in PCA
FAO	-	Food and Agriculture Organization
GoK	-	Government of Kenya
IL	-	Intermediate Lowland
IPGRI	-	International Plant Genetic Resource Institute
LH	-	Lower Highlands
LM	-	Lower Midlands
MAS	-	Marker Assisted Breeding
MoA	-	Ministry of Agriculture
ND	-	Nano Drop
NPK	-	Nitrogen, Phosphorus and Potassium fertilizer
PCR	-	Polymerase Chain Reaction
RCBD	-	Randomized Complete Block Design
S1	-	Season 1
S2	-	Season 2
SAS	-	Statistical Analysis Software
SNK	-	Student Newman Keuls
UH	-	Upper Highlands
UM	-	Upper Midlands
UPGMA	-	Unweighted pair group method with arithmetic average
XLSTAT	-	Excel Statistics software

LIST OF SYMBOLS

%	-	Percentage
Ca	-	Calcium
Cm	-	Centimeters
Dm^3	-	Cubic decimeters
DPIP	-	phenol indo-2, 6- Dichlorophenol,
Fe	-	Iron
g	-	Grams
Ha	-	Hectares
HCl	-	Hydrochloric Acid
HNO_3	-	Nitric Acid
K	-	Potassium
Kg	-	Kilogram
L	-	Litres
m	-	Meters
mg	-	Milligrams
mm	-	Millimeters
Na	-	Sodium
NaOH	-	Sodium Hydroxide
NH_3	-	Ammonia gas
P	-	Phosphorus
α	-	Alpha
γ	-	Gamma
^oC	-	Degrees Centigrade

ABSTRACT

African horned melon (*Cucumis metuliferus*) is an indigenous crop belonging to the family Cucurbitaceae. The crop has been neglected despite its high potential. Therefore, to conserve the biodiversity of this crop, there is need to promote its domestication and production. However, this can only be realized if its morphology, agronomic and nutritional value is understood. The objective of this study was to determine the agro-morphological performance and nutritional composition of horned melon accessions obtained from selected agro-ecological zones in Kenya. The study was conducted at the University of Embu research farm for two cropping seasons; October to January 2018 and March to June 2019. The experiment was laid out in a randomized complete block design with nineteen accessions replicated three times. The accessions were planted in experimental plots measuring 3m x 3m at a spacing of 1m by 1m. Morphological and agronomic characterization was based on modified International Plant Genetic Resource Institute (IPGRI) descriptors for melon. Data was recorded from four plants per plot per replicate. The fruit content of Fe and P were determined using atomic absorption spectrophotometry while Na and K were determined using flame photometry procedure. Vitamin C content was estimated by titrimetric method. Sugar content was determined using a brix refractometer. The qualitative and quantitative data obtained from morphological and agronomic characters were organized in a matrix and subjected to cluster analysis. A dendrogram was then constructed using unweighted pair-group method with arithmetic average. Agronomic and nutritional data was also subjected to analysis of variance using XLSTAT 2019 statistical software and means separated using Students Newmans Keuls test at 95% level of confidence. Significant differences ($p<0.05$) were observed in all the quantitative traits except the number of branches and main vine length. However, qualitative variations were only observed in fruit shape, rind colour and seed shape. In both seasons, the dendrogram separated into 5 supported clusters with the diversity between classes being 63.82% in the first season and 68.84% in the second season and diversity within classes being 36.18% in the first season and 31.16% in the second season. Accessions from Rongo, Wote, Siakago, Maragua, Oyugis and Meru had the highest fruit number and fruit weight for both season hence they can be more preferred by farmers and consumers. The accessions also varied significantly

($p<0.05$) in their nutritional composition except the Moisture Content and the Vitamin C. The composition of the mineral contents in the fruits followed the order K > P >Na >Fe .Potassium (K) content ranged from 249.52mg/100g-165.17mg/100g for Kangundo and Embu accessions respectively. Sodium (Na) ranged from 2.27mg/100g- 1.10mg/100g for Mitunguu and Siakago accessions respectively. Phosphorus (P) range was 40.49mg/100g-8.76mg/100g for Migori and Machakos accessions respectively. Iron (Fe) ranged from 2.61mg/100g-0.80mg/100g for Kianjokoma and Maragua accessions respectively. The horned melon accessions tested in this study showed a high agro-morphological and nutrition variation. The study recommended the accessions from Kehancha, Embu and Siakago which recorded highest sugar content across seasons to be used by plant breeders to improve on taste which is considered to be bland by some consumers.

CHAPTER ONE
INTRODUCTION

1.1 Background

Horned melon (*Cucumis metuliferus*), (2n = 2x = 24), is an annual vine in the family, *Cucurbitaceae (*Wang *et al.*, 2007). It was named "horned melon" because the fruit has horn-like spines (Wang *et al.*, 2007). The species name was derived from the Latin word, *metula*, meaning a small pyramid, and *ferus*, meaning bearing (Usman *et al*., 2015) referring to the sharp spines on the fruit. The family comprises of about 118 genera and 825 species with their members spread mainly in regions of tropical and subtropical worldwide (Wang *et al.*, 2007). The *Cucurbitaceae* family includes two subfamilies *Zanonioideae* and the *Cucurbitoideae. Cucurbitoideae* comprises of eight tribes one of which is *Melothrieae* which includes the genus *Cucumis* (Rabei *et al.*, 2013). Apart from horned melon, the genus *Cucumis* has more than 30 other species including cucumber (*C. sativus*) and melon (*Cucumis melo*) both of which are widely grown in Kenya (FAO, 2011). It also includes West Indian gherkin (*C. anguria*), the Aardvark cucumber (*C. humifructus*) that grow underground and the paddy melon (*C. myriocarpus*) which is known to be toxic (Foster, 2003; Usman *et al*., 2015) and is rarely grown. Horned melon has many common names like jelly melon, Kiwano (English), Melano (Israel), bitter wild cucumber (South Africa), 'bùuràr zaàki' (Nigeria), thorn melon among others (Wannang, 2011).

Horned melon has a natural habitat ranging from semi-arid highlands to low-altitude riverine semi-evergreen forest (Berlingeri & Crespo, 2012). Horned melon dominates both tropical and sub-tropical areas (Wilkins-Ellert, 2004). It cannot tolerate cold and mist conditions (Mey, 2014). Horned melon grows at an altitude range of 210 to 1800 m above sea level (Bester & Condy, 2013). It usually grows in shallow or deep, well-drained, mostly alluvial sandy soil on river banks, in river beds or flood plains (Berlingeri & Crespo, 2012). It has also been shown to grow in clay or loam soil and rocky slopes which are rich in nutrients and have full sunlight exposure and a pH range of 6.0 and 6.5 (Usman *et al.*, 2015). It climbs on trees or shrubs in various vegetation types such as

forest edges, semi- evergreen forest, deciduous woodland (often with Acacia), savanna or grassland. It also grows in disturbed areas and abandoned land (Anon, 2014).

The optimum growing temperature for horned melon ranges between 20 - 30°C (Aliero & Gumi, 2012). The plant's growth is not greatly affected by temperatures as high as 40°C although flowering seems to be affected by temperatures over 30°C (Aliero & Gumi, 2012). At temperatures above 35°C, germination is also greatly inhibited (Aliero & Gumi, 2012). The plant can do well with as little as 350 to 550 mm of rainfall per season and dry air is beneficial during the harvest period (Cantwell, 2011). Semi-arid climate and warm season rainfall enhances the fruit ripening stage, enabling the fruit to develop full flavor (Aliero & Gumi, 2012). Flowering and fructification of the fruit is affected by photoperiod; flowering requires short days of less than 14 hours, with a minimum inductive cycle of about eight weeks (Aliero &Gumi, 2012).

Cucurbits are widely cultivated around the world and are among the most important fruits consumed in Africa since they are rich in several vitamins and minerals (Deguine *et al*., 2015). They are ranked among the major vegetable fruits grown in Kenya and exported abroad for their nutritional value and economic significance as foreign exchange earners (Tshilidzi *et al*., 2016). The major species of cucurbits grown in Kenya are butternut (*Cucurbita moschata*), pumpkin (*Cucurbita maxima*), cucumber (*Cucumis sativus*), courgettes (*Cucurbita pepo*) and watermelon (*Citrullus lanatus*) (HCDA, 2016). The major melon producing areas in Kenya are Makueni, Tana River, Kilifi, Migori, Kwale and Meru counties accounting for 69% of the national value (HCDA, 2014). Recently, production of horned melon has been reported in many parts of Kenya including Meru, Embu, Kisii, Homabay, Kitui and Machakos counties (Bob, 2018). Globally, the production of horned melon has increased in the recent decades with its major exporters being New Zealand, Israel and Kenya which export the fruit to Europe (Cantwell, 2011).

1.2 Statement of the Problem

Despite the numerous advantages of horned melon over other fruits, the fruit is hardly known in most parts of the world with only one aspect of the stunning visual appeal being known and well explained by scientists (Wilkins-Eller, 2004). Although Kenya is listed among the few exporters of horned melon (HCDA, 2014), the fruit remains less popular among small scale Kenyan farmers and not widely grown in many parts of the country. The crop is therefore underutilized despite its high nutritional value and economic potential. This is attributed to the lack of awareness of its nutritional and economic value among Kenyans (Bob, 2018). Its agronomic requirements are also not well understood (Bob, 2018). Some horned melon accessions have been identified in various agro-ecological zones in Kenya but their agro-morphologic traits have not been studied (Bob, 2018). Consequently, no selection has been conducted on this crop despite its high economic and nutrition potential. It is expected that where this plant already exists in the wild or introduced in farmers' fields, a wealth of agro-morphological variation that can be utilized in its improvement would be found. There is therefore need to evaluate the agronomic performance, morphological trait and nutrition composition of various accessions of horned melon available in Kenya.

1.3 Justification

Horned melon has many health benefits including slowing of aging, facilitation of weight loss, improving eye health, prevention of cancer and many others (Usman *et al*., 2015; Reshmika & Sameer, 2016). Promotion of this high value crop can go a long way in improving food and nutritional security as well as economic livelihoods of many small scale farmers in Kenya (Bob, 2018). The long shelf life of its fruits and ability to retain the decorative appeal for many months at room temperature is an additional desirable attribute that makes it attractive to many small scale farmers and consumers (HCDA, 2014). The crop is being promoted as an important horticultural fruit with growing demand within and internationally, including United Kingdom (HCDA, 2014). Horned melon is also drought and heat tolerant and has the ability to germinate under high saline conditions (Lysne, 2015) hence qualifies as one of the climate smart crops with a wide genetic diversity in Africa. In addition, it is resistant to root knot nematodes that majorly

attack the Cucurbitacea family (Walters *et al*., 2006). Cucurbit breeders have therefore developed a strong interest in the crop since it is a pool for useful genes for the improvement of the cucurbit crops (Yagi *et al.*, 2014). Determination of morphological and agronomic characteristics of horned melon is the first step towards its genetic improvement and promotion of the crop's production among small holder farmers in Kenya. This study provides useful information on the agro-morphological diversity among Kenyan accessions of horned melon which will be useful when initiating the breeding program and to enhance its promotion among farmers.

1.4 Research Questions

i. What is the level of morphological variation between different horned melon accessions available in Kenya?
ii. How do different horned melon accessions from different agro-ecological zones in Kenya vary in their agronomic performance?
iii. How do different horned melon accessions from different agro-ecological zones in Kenya vary in their nutritional composition?

1.5 Research Objectives

1.5.1 Broad Objective

To determine the morphological variation, agronomic performance and nutritional composition of horned melon accessions from different agro-ecological zones in Kenya.

1.5.2 Specific Objectives

1. To evaluate the morphological variation of different horned melon accessions available in Kenya using morphological characteristics.
2. To evaluate the agronomic performance of different horned melon accessions available in Kenya.
3. To determine the nutritional composition of different horned melon accessions available in Kenya.

CHAPTER TWO
LITERATURE REVIEW

2.1 Origin of Horned Melon

Horned melon is native to Sub-Saharan Africa (Berlingeri & Crespo, 2012; Bester & Condy, 2013). The crop occurs naturally throughout the tropical and sub-tropical semi-arid regions of Africa, from South Africa, Somali, Senegal (Wilkins-Ellert, 2004), Nigeria, Namibia, Botswana and Swaziland (Usman *et al.*, 2015). The crop was introduced to Australia 70 years ago as a weed (Usman *et al*., 2015) and later acclimatized in countries like California, New Zealand and Kenya (Mey, 2014). In Kenya, the species *metuliferus* was initially growing naturally in the wild before being domesticated (Bester & Condy, 2013). The birds, wild animals and bushmen are largely responsible for the dispersal of seeds from the native to the farms where they are domesticated since they eat the ripened fruits in the wild then disseminate (Usman *et al*., 2015). Dispersal is fast because the juicy ripe fruit is easily eaten due to lack of a hard outer skin (Welman, 2009).

2.2 Botanical Description of Horned Melon

Horned melon is a stretching out, trailing herbaceous annual vine that climbs over bushes and trees in the wild (Anon, 2014). It has thin and hairy stems that are very long texture (Mey, 2014). Vegetative parts are covered with spreading stiff white or brown hairs resulting in a rough texture (Mey, 2014). The stems grow to a maximum height of 5 meters, radiating from a woody rootstock with spreading hairs. Each vine is capable of producing up to 100 fruits (April *et al*., 2018) The tendrils of horned melon are slightly weak hence should be supported (Anon, 2014). The leaves are dark green, heart shaped, shallowly lobed and long-stalked. It has thin, unbranched and curling tendrils coming from the axils (Dembitsky *et al*., 2011).

Horned melon is a monoecious plant with flowers that are small sized, bright yellow, funnel-shaped, axillary and opening to 5 lobes (Lysne, 2015). It has female flowers with yellow corolla with an area of 8–15mm by 4–12 mm (Aliero & Gumi, 2012). The ovary is 20 mm long, green with numerous dark green fleshy spines ending in stiff bristles

(Lysne, 2015). The pistillate enlarges to form the fruit which grows above a prickly green ovary (Mey, 2014). The staminate usually appears several days before the female flowers (Mey, 2014). It forms in clusters of 1 to 4, with a short, green to pale yellow corolla with an area of 5 to 13 by 2 to 8 mm united in lower third pedicillate (Usman *et al.*, 2015). The fruit is ellipsoid-cylindrically shaped and can attain a maximum area of 60 to 130 mm by 28–94 mm when mature (Bester & Condy, 2013). It is normally light green when immature and bright orange at ripening (Weng, 2010). Ripe fruit has jelly-like flesh with a refreshingly fruity taste, and texture similar to a passion fruit while the unripe fruit remains dark-green (Mey, 2014). The skin has a broken pattern of light, scribbly interlacing lines, with sharp spines at the top (Mey, 2014). The spines are stout, broad-based, fleshy with an area of 6–14 mm by 2–5 mm and white to brown bristle-tipped (Weng, 2010). The fruit "flesh" is translucent, green, and filled with whitish seeds. Seeds are ellipsoid shaped and flattened and can be true-to-type unless there is outcrossing (Cantwel, 2011).

2.3 Uses of Horned melon

The fruits of horned melon occur in two forms namely the bitter and non-bitter forms, which occur mostly in the wild state (Usman *et al.*, 2015). The bitter form contains cucurbitacins or triterpenoids, which are highly toxic compound hence not fit for human consumption while the non-bitter form has been found to be less toxic and is cultivated in many parts of the world (Usman *et al*,. 2015). However, the fruit has a bland taste (Bester & Condy, 2013) which makes it less popular like other cucubitacins although some African countries like Botswana, Zimbabwe and South Africa are already growing sweeter selections (National Research Council, 2008).

Horned melon has high economic value which has not been fully exploited (Aliero & Gumi, 2012). The flesh and the seeds can be eaten raw and the immature fruits can also be relished like cucumber but the nutritional value is rated twice higher than that of cucumber (Lim, 2012; Anon, 2014). The fruit can be eaten fresh after being sprinkled with sugar or salt to enhance its flavor then gently scooped using a spoon (Weng, 2010). The fruit can also be sliced and added to tropical fruit salads (Lysne, 2015).

The high moisture proportion in the fruit provides a good source of water for animals and human in the arid and semi-arid areas (April *et al.*, 2018). Generally, the ripe fruit can be used for decoration purposes due to its ornamental appearance (Cantwell, 2011). The pulp and the seeds of horned melon can be blended in a food processor for making beverages for refreshments (April *et al.*, 2018). The pulp can also be spooned over sorbets, yoghurts and ice creams to enhance the flavour (Weng, 2010). It can also be used as a substitute for vinegar in salad dressing (Mccormack, 2005). Both the seeds and the skin of horned melon are edible (Anon, 2014). The wild fruits can be baked whole like in Kalahari Desert and can be sliced and dried for future use (Mey, 2014). The leaves can be boiled and eaten like spinach when young (Anon, 2014). Various amino acids, fatty acids and volatile compounds that are present in *C. metuliferus* can be used to alleviate malnutrition (Karaye *et al*., 2012).

Horned melon has also been shown to have numerous uses in the pharmaceutical industry (Weng, 2010). The various health benefits of the plant are due to the phytochemical constituents that are present in the fruit (Usman *et al.*, 2015). The plant has several groups of secondary metabolites which account for its use as food or in the treatment of various ailments (Weng, 2010). These include alkaloids, carbohydrates, cardiac glycosides, flavonoids, saponins, tannins, steroids and terpenoids (Motlhanka, 2008; Jimam *et al*., 2010; Gotep, 2011; Usman *et al*., 2014). Beta carotene and vitamin A contained in the pulp is of importance in boosting the immune system, for good night vision and for healthy skin (Usman *et al*., 2015). Consumption of *C. metuliferus* also increases the values of blood parameters: packed cell volume, haemoglobin, red blood cell and white blood cell counts (Usman *et al.*, 2014). It also helps in vision health, strong bones and teeth and reducing heart burn (Sultana & Rahman, 2014).

The seeds contain linoleic and oleic acids which are believed to help with the lowering of blood pressure (Hossain *et al*., 2011). They also contain two antioxidants namely γ-tocopherol and α- tocopherol which are organic types of vitamin E which have many health benefits to the body cells and organs, such as the red blood cells, skin, muscles, nerves and heart (Weng, 2010). Vitamin E also helps to neutralize the damage from free

radicals which can cause cancer and cardiovascular diseases (Usman *et al.,* 2014; Usman *et al*., 2015). Isolated alkaloids from *C. metuliferus* have also been shown to have some antiviral effects (Wannang *et al.,* 2010) and anti-ulcer property (Wannang *et al*., 2009; Omale *et al*., 2011). Research conducted by Jimam *et al.* (2010) and Gotep (2011) suggested that the glycosides extracted from the fruit pulp possess anti-diabetic effects against diabetes mellitus (Weng, 2010). The high level of zinc in *C. metuliferus* could have an effect on fertility through increase of sperm count and sperm motility (Wannang *et al.,* 2008).

2.4 Storage of Horned Melon

The stage of maturity at harvest is considered critical for an adequate post-harvest life and eating quality (Cantwel, 2011). Ripening and accumulation of sugars happens during the last 10 days of the growth period in horned melon (Weng, 2010). The fruit is very sensitive to chilling and mist condition (Mey, 2014). During harvesting, one should wear gloves to prevent the hands from being pricked (National Research Council, 2008). This is due to the sharp spines that surround the whole fruit. The fruit can be stored at room temperature for six months, making them good ornamental fruits (Cadet, 2014). This is done by cutting the fruit into half then the flesh scooped and the shell used as a bowl (Weng, 2010). However, the fruit should not be stored near apples or bananas that produce much ethylene (Usman *et al.,* 2015). Qualities like big sizes (250g), yellow-orange exterior colour and flavoured pulp are required for market purposes (Reshmika & Sameer, 2016). During packaging, the fruits are packed in boxes in single layer trays (Weng, 2010). This is to prevent the spine puncture that lowers the storage duration of the fruit (Weng, 2010).

2.5 Nutritional Composition of Horned Melon

Horned melon occurs in two forms namely the bitter form which contains cucurbitacins (triterpenoids), which is a mix of highly toxic compound (Kaushik *et al*., 2015) and the non-bitter form which has been found to be less toxic and has also been widely cultivated (Wannang, 2011). The non-bitter form can be described as flavorless or rather bland

(pineapple-banana-like) taste (Lysne, 2015). Major nutrients contained in horned melon are Iron (32.88%), Magnesium (22.14%), Vitamin C (13.67%), Phosphorus (12.29%) and Vitamin B6 (11.31%). Other minor nutrients include; Vitamin A, Vitamin B5, Vitamin B3, Vitamin B2 and beta-carotene, (Dembitsky *et al*., 2011; Usman *et al.*, 2015). Some secondary metabolites like the alkaloids, flavonoids, saponins, saponins glycoside, volatile oil and cardiac glycosides are also present in both the leaves and the seeds (Aliero & Gumi, 2012).Wilkins-Ellert, (2004) reported that horned melon fruit comprised of 90% moisture, about 10% protein, 6% fat, and 45% carbohydrate.

Sugar is considered to be one of the basic taste qualities for most fruits and vegetables. Sweet taste induces preference thus enhances consumption and the vice versa (Cadet, 2014). The levels of sugar in horned melon are relatively low compared to netted melons which is 7.86g/100g (Suslow *et al.,* (2013). Andrés *et al.* (2016) reported that horned melon fruit contains about 90% moisture. The high moisture content compares with that of other cucurbits including cucumber, netted melons, watermelon, summer squash and winter squash that are reported to have a moisture content of 96%, 90.15%, 92.6%, 94% and 89% respectively (Cantwell & Suslow 2013). The moisture content indicates the lifespan of the fruit (Fellows, 2000) and high moisture is typical for fresh fruits at maturity (Abiodun & Adeleke, 2010). The high moisture proportion in the cucurbits promotes them a good sources of water for animals and human in the arid and semi-arid areas (April *et al.,* 2018).

Only about a third to a half of the vitamin C in horned melon can be obtained from fresh oranges (Andrés *et al.,* 2016). Studies conducted by Consoli & Camargo (2015), Bello *et al.* (2014) and USDA (2011) on Cucurbits reported that cucumber, netted melon, watermelon, summer squash, winter squash and ash gourd had vitamin C content of 4.7 mg/100g, 38.7 mg/100g, 7.0 mg/100g, 14.7 mg/100g, 12.3 mg/100g and 13 mg/100g, respectively. Lim (2012) reported that horned melon contains twice the amount of Vitamin C found in cucumber which also varied with the levels observed in this study. According to Lee and Kader (2000), vitamin C content can be influenced by pre-harvest and post-harvest factors including prevailing climatic conditions and cultural practices.

A fresh fruits of horned melon contain 2 mg/100g of Na (Rudrappa, 2019). Previous studies conducted on other cucurbits reported that plants like cucumber, watermelon, summer squash and winter squash had Na content of 1.1mg/g, 1mg/100g, 2mg/100g and 4mg/100g respectively (USDA, 2011). Sodium is very essential in maintaining the water balance within the cells, muscle contraction and nervous system functions (Weng, 2010). Low sodium and high levels of K in human diet have been reported to be beneficial in the prevention of high blood pressure (Nerdy, 2018). The nutrient Na is only required in small quantity and when in excess, it is excreted by the kidney (Noubiap *et al*, 2015). This makes horned melon a suitable fruit in regulating the blood pressure which is a major cause of death in the world (Weng, 2010).

Rudrappa (2019) reported that fresh fruits of horned melon contain 123 mg/100g of K which is relatively lower than what was observed in most accessions in this study. Previous studies on other cucurbits reported that edible fruits of summer squash, winter squash, watermelon and cucumber had high potassium content of 195mg/100g, 350mg/100g, 100mg/100g and 149mg/100g respectively (Masabni *et al.,* 2011; Cantwell & Suslow 2013; Suslow *et al*., 2013). Potassium has much influence on the fruit quality for instance the fruit colour, appearance, size, acidity and improved drought resistance (Kumar et al., 2006). It also has many functions like enhancing plant metabolic processes, increased root growth, reduced water loss and improved resistance to pests and diseases (Kumar et al., 2006). The benefits of high K intake in human bodies include prevention of stroke, coronary heart disease and hypertension (Weaver, 2013).

Rudrappa (2019) reported that the P content of horned melon is 37 mg/100g. Comparable levels of 35mg/100g and 32mg/100g of P were reported in summer and winter squash by Bello et al. (2014). In the same study they reported relatively lower levels of 17mg/100g and 10mg/100g of P in cucumber and watermelon. Phosphorus is needed in the body for maintaining the cell structure, regulation of cellular signalling, maintaining acid-base homeostasis and bone mineralization (Mcclure *et al*., 2014). Recommended P intake for

adults is 600-700mg/day hence consumption of a few horned melon fruits per day is enough to achieve the daily P requirement (Karp, 2013).

Rudrappa (2019) reported that horned melon contain 1.13 mg/100g of Fe. Studies conducted on other cucurbits showed that cucumber, netted melon, watermelon, summer squash and winter squash to have 0.3mg/100g, 0.21mg/100g, 0.5mg/100g, 0.5mg/100g and 0.6mg/100g of iron content respectively (Nair & Iyengar, 2009; Brown & Hodgkin, 2015). Horned melon therefore contains more than double the levels of Fe contained in other cucurbits thus making it an important source of this micronutrient (Weng, 2010). Iron plays a role in oxidation metabolism, transport and cellular proliferation (Nair & Iyengar, 2009). Lack of Fe in the body causes anaemia which is a disease that affects all ages in a population but especially breast feeding and the pregnant mothers (Lonnerda *et al*., 2006). The range required for adults is 8.7mg/day in males and 14.8mg/day in females hence consumption of a few horned melon fruits per day is enough to achieve this daily requirement (Weng, 2010). There was significant positive correlation between Fe and K content. This concurred with the finding of Asri & Sonmez (2012) who reported a positive correlation between Fe and K content in tomatoes.

This study was the first attempt to compare the nutritional composition of different accessions of horned melon available in Kenya.

2.6 Production Constraints of Horned Melon

The seeds of horned melon are reportedly hard to germinate if not well treated through fermentation for about 5-7 days at room temperature to remove the jelly like substance which contains some inhibitory factor for germination and then air dried (Gisbert *et al.,* 2011; Aliero & Gumi, 2012). Fermentation helps to separate the seed from the pulp, removes germination inhibitors and inhibits or kills certain disease organisms (Mccormack, 2005). Fermentation can also introduce beneficial fungi, and in some cases, may help overcome or prevent detrimental bacteria (Mccormack, 2005). The plant yield is reported to be low especially the ones growing in the wild (Gumi, 2012). However, some studies have stated that like other plants in the Cucurbitacea family, the yield and the fruit quality are considerably affected by water requirements, sowing dates, fertilizer

application rates and plant densities (Welman, 2009). Although the natural insect pollinators are not well known, honeybees are the efficient pollinators (Wilkins-Ellert, 2004). They are not naturally attracted to the flowers of horned melon but they only visit the plant when no other alternative plant is around (National Research Council, 2008).

African horned cucumber is highly resistant to diseases including viral infections, wilts and other root problems and has been used commercially as a cucumber rootstock (Walters *et al.,* 2006; Guan *et al.,* 2014). Like all Cucurbitacea family crops, horned melon can also be attacked by pests like whitefly, red spider mite and aphids especially when grown in extremely warm areas or with high levels of nutrients which encourage soft growth (Sigüenza *et al.*, 2005). The plant cannot be intercropped with other crops due to its spreading nature. The sharp spines of the fruits may injure the pickers during harvesting, thus requiring them to wear gloves (Cantwell , 2011). The main culinary constraint of horned melon is that most people find the fruit not appealing as a foodstuff as the appearance certainly can be perturbing (Usman *et al.,* 2015). However, in countries like Zimbabwe, Botswana and South Africa, the sweeter selection is currently grown (National Research Council, 2008). In Kenya, there is no available data on any attempts towards taste improvement.

2.7 Genetic Potential of Horned Melon

In cucurbits, micro-organisms (bacteria) which cause diseases like water spots on the fruits, viruses (notably, zucchini virus) and fungi especially in a wetter climate can be a problem (Sharma *et al.,* 2016). Unlike other cucurbits such as cucumber and melons, horned melon has been shown to be highly resistant to root knot nematodes (Walters *et al.*, 2006; Yagi *et al.*, 2014) whitefly, Papaya ring spot virus, and Watermelon mosaic virus (Huang *et al.,* 2009a). The only enemy of horned melon in the wild is the caterpillar that attacks the fruits lying on the ground (Sharma *et al.,* 2016). Resistance to root-knot nematodes (*Meloidogyne incognita*), which is a major impediment in cucumber production (Sigüenza *et al.,* 2005) exists in *Cucumis metuliferus,* but efforts of making crosses of *Cucumis* species with cucumber by many researchers have not succeeded

(Walters & Wehner, 2002). The only alternative for utilizing *C. metuliferus* resistance genes is somatic hybridization using protoplast fusion (Weng, 2010).

Apart from disease and pest resistance, *C. metuliferus* has also been shown to possess drought and heat tolerance as well as the ability to germinate under high saline conditions (Lysne, 2015). These attributes have endeared horned melon to many cucurbit breeders in the world but the crop has not been widely studied in Kenya. It is therefore of uttermost importance to evaluate the diverse accessions of horned melon in Kenya to understand their morphology and agronomic potential. The proposed study will greatly contribute not only to agronomic improvement of horned melon but also to the field of cucurbit breeding. Collection of different accessions will also broaden the available genetic variability. This can be used by plant breeders for the improvement of undesirable traits in the Kenyan accessions like the bland taste.

2.8 Importance of Genetic Diversity in Crop Production

The evolution of new biotypes of pests and diseases and climate change has increased challenges to crop breeders, who would like to increase crop production by introducing resistance to multiple biotic and abiotic stresses (Hayashi *et al.,* 2004). Genetic diversity improves the chances that the crop will cope better with insects, diseases or environmental stresses such as drought, heat or floods (Govindaraj *et al.,* 2015). The different characteristics of the diverse varieties can potentially reduce the losses as a result of these stresses (Sharma *et al.,* 2016). When only one plant variety is grown, the vulnerability of the crop to the stresses becomes higher (Sharma *et al.,* 2016).

The expected climatic and environmental changes will place unprecedented stress on agricultural systems and, as a result, the most diverse cropping systems are likely to be the most adaptable (Engels *et al.,* 2014). An adequate range of crop and varietal diversity allows farmers to undertake practices that protect them against different hazards and risks, and provide them with a kind of insurance against the unknown, as such farmers and farming systems become more resilient to natural hazards (Engels *et al.,* 2014). Different horned melon accessions collected from different agro-ecological zones are

likely to possess appreciable genetic diversity since they received different weather patterns and different nutrient compositions hence they can be exploited by plant breeders for the improvement of the crop (Engels *et al.,* 2014).

2.9 Measures of Diversity in plants

Diversity is important in survival of all living organisms. Genetic variability is the variation in alleles or DNA sequence in the gene pool of a population (Munene *et al.*, 2018). Genes are fundamental units of biological variation that helps in shaping and defining individuals and population, species, sub-species and alternatively the kingdoms of life on earth (Mukhopadhyay & Bhattacharjee, 2016). In determining the uniqueness of a phenotype and selection of parents for hybridization, information concerning germplasm diversity and genetic relationship is very important in plant breeding (Motlhaodi *et al*., 2009). Genetic diversity plays a role in the selection of breeding material and determining the performance of the species (Mukhopadhyay & Bhattacharjee, 2016). Various factors affecting the measures of genetic variation include genetic composition of the population, reproduction system and number of individuals being sampled in each population (Munene *et al*., 2018). There are several measures of genetic diversity (Motlhaodi *et al*., 2009). The first is genetic base which indicates how frequently a line appears in in a commercial variety of a particular crop (Motlhaodi *et al*., 2009).The second is genetic diversity which is the difference among the populations (Motlhaodi *et al*., 2009).The third is alleleic diversity which is used when the genetic marker data can be interpreted by an allele model and heterozygosity is the most commonly used measure of genetic variation with population (Motlhaodi *et al*., 2009; Munene *et al*., 2018).

2.10 Phenotypic Variation among crop plants

Phenotypic variation is the tendency of an organism to vary from the outward appearance (K'opondo *et al*., 20011). There are three components of phenotypic variability which includes canalization, development stability and morphological integration (Thi *et al.,* 2018). Canalization is the property of an organism that ensures similar phenotypic expressions within a group by boosting development against both genetic and

environmental perturbations (Marriog *et al*., 2001). Developmental stability is the property of an organism that promotes variation of micro-environmental origin within the organism (K'opondo *et al*., 20011). It therefore ensures consistent phenotypic expression within individuals given a specific genotype and the environment outside the organism (Munene *et al*., 2018). Morphological integration refers to the phenotypic interdependence of two or more structures that reflects common development or function (Watson and Eyzaguirre, 2002). It is estimated by the level of covariation or correlation among structures (K'opondo *et al*., 20011). Strong covariation between traits indicates a high degree of integration and is thought to be caused by shared developmental, functional or genetic influences (Meng *et al*, 2006). Among the earliest genetic markers used in germplasm management are the morphological and phenotypical methods (Rabei, 2013). The methods depend on discrimination of individual accessions based on physical traits like leaf shape, growth habit, maturity cycle and flower traits (Thi *et al*., 2018).

Phenotypic variability results from both environmental factors and genetic factors (K'opondo *et al*., 20011). Phenotypic characterization involves characterizing advanced morphological traits with agronomic importance (He *et al.,* 2006; Raghami *et al.*, 2014). Morphological traits are important in any plant breeding because they are the first step in genetic relationship study (Pavlicev & Cheverud, 2011). There are, however, some factors limiting phenotypic characterization (K'opondo *et al*., 20011). For example, it is difficult to characterize a large collection of germplasm hence it only meet criteria for few desirable traits (Thi *et al.*, 2018). In addition, phenotypic traits are influenced by environmental factors like rainfall and temperature thus leading to difference in expression hence complicating interpretation of results (K'opondo *et al*., 20011). Therefore, the plant must be given extensive trials under the same environment and season in order to give a valid comparison (Willmore *et al*., 2007). Lastly, the traits of interest may not be significantly different at an early stage hence the plant is required to grow to maturity before identification (Munene *et al.,* 2018). Despite the numerous demerits, phenotypic and morphological characterization are still very important measures in genetic variation because they are reliable (Rabei *et al.,* 2013).

2.11 Horned Melon Germplasm Collection

Germplasm consist of living genetic resources like seeds or tissues that are maintained for the purpose of animal and plant breeding, preservation, and other research uses (Volis & Blecher, 2010). These resources may take the form of trees growing in nurseries or seed collections stored in seed banks (Raghami *et al.*, 2014). Germplasm collections can range from collections of domesticated breeding lines that have undergone extensive human selection to wild species (Kathayat *et al*, 2019). Germplasm collection is important for the maintenance of biological diversity and food security (Raghami *et al.*, 2014). The seedlings derived from the commercial cultigene of horned melon do not exhibit much variability (Raghami *et al.*, 2014). However, accessions from the wild have a wide phenological variability which can be used for selection and breeding for improved traits (Varshney *et al*., 2007).

A key step of initiating plant breeding is establishing a germplasm bank (Raghami *et al.*, 2014). This prevents extinction of landrace of any desirable cultivated crop species (Rosenow & Dahlberg, 2000). This involves collection of basic information concerning the crop which is recorded at the time of collection for example the crop origin (Raghami *et al.*, 2014). This helps in identifying possible duplicates and new entries and aids in planning for further crop collection (Ojiewo *et al*., 2010). Previous horned melon accessions have been maintained by the gene bank (Munene *et al,*. 2018).

Another source of germplasm includes the farmers' collection which is maintained *in situ* (Raghami *et al.*, 2014). This source, however, possesses a high risk to their extinction due to high human activity that leads to loss of natural habitat (Raghami *et al.*, 2014). Hence conservation through breeding is most preferred since it enhances and stabilizes the available horned melon accession (Munene *et al,*. 2018). Categorizing of the available accession into morphologically distinct groups is very useful and will help in rescuing the existing accession from erosion and conserving the novel genes ((Raghami *et al*., 2014).

CHAPTER THREE
MATERIALS AND METHODS

3.1 Sampled Regions

The major melon producing areas in Kenya are Makueni, Tana River, Kilifi, Migori, Kwale and Meru accounting for 69% of the national value (HCDA, 2014). However, there is very scanty information about the production of horned melon in Kenya since most information on production has not been published. The sampled counties were therefore selected based on unpublished information obtained from various sources. The local community was requested to guide to where the samples could be obtained in the locality sampled.

3.1.1 Embu County

Embu County is in the Eastern part of Kenya. Embu lies at a latitude of -0.5311 and longitude 37.4506 (Gachimbi, 2002). Melon production in Embu County is mainly done in Mbeere North and Mbeere South sub-counties which are found in lower midland (LM) 3, 4 and 5 agro ecological zones and are characterized by hot and dry semi-arid conditions (Gachimbi, 2002). The two sub counties mainly engage in indigenous livestock keeping and growing of drought-resistant crops such as millet, sorghum and green grams (MoALF, 2016a). The area receives an annual rainfall ranging from 640 mm to 2000 mm (Gachimbi, 2002). The soils are mainly hemic nitisols derived from basic volcanic rocks. They are deep, highly weathered with friable clay texture and moderate to high inherent fertility (FAO, 2011). The horned melon produced are majorly consumed locally. The experimental materials were collected from Siakago (LM3), Kiambere (LM4), Kianjokoma (UM1) and Embu (UM2) (Gachimbi, 2002).

3.1.2 Meru County

Meru County is reportedly among the leading producers of horned melon. The County lies on the eastern slopes of Mt. Kenya covering a total area of 693,620 hectares (GoK, 2013a). It lies at a latitude of 0.0463 and a longitude of 37.6559 (Jaetzold *et. al.*, 2010.The County is divided into four agro ecological zones ranging from UH3 to LM6 (Jaetzold *et. al.*, 2010). Meru is the main producer of horned melon in Kenya that are exported to the European countries. The study targeted the warmer zones particularly the

LM1 to LM5 with average temperatures ranging from 20.9ºC to 24ºC and average precipitation of 580-1,600 mm (Jaetzold *et. al.*, 2010). These areas lie on an altitude range of 750-1300 m above sea level (MoALF, 2016b). The county is mainly characterized by black cotton soils that form crust when dry and easily get flooded when it rains (Jaetzold *et. al.*, 2010). The experimental materials were collected from Meru and Mitunguu regions.

3.1.3 Makueni County

Makueni County is located in the South Eastern part of Kenya. It lies at a latitude of -1.8041 and a longitude of 37.6203 (Jaetzold *et. al.*, 2010).The County is characterized by a low-lying terrain except for the hilly areas such as Kilungu Hills, Mbooni Hills and Chyulu Hills (Jaetzold *et. al.*, 2010). Several agro-ecological zones are found in the County. These include lower highland (LH) 2 receiving an average annual rainfall of 1000-1300 mm; upper midland (UM) 2 receiving an average annual rainfall of 980-1200 mm; UM 3 receiving about 950-1050 mm of average annual rainfall; UM 4 receiving about 800-950mm of average annual rainfall and UM 5 receiving about 600-750 mm of average annual rainfall (Jaetzold *et. al.*, 2010). Others are LM 3 (cotton zone) with an average rainfall of 800-900mm of annual rainfall, LM 4 (marginal cotton zone with an average annual rainfall 700-850 mm, LM 5 (livestock-millet zone), receiving about 650-750mm of average annual rainfall (MoALF, 2016c). The soils are largely humic nitisols, which are well-drained, extremely deep, dusky red to dark reddish brown, of friable clay and with high inherent fertility and acidic humic topsoil (Jaetzold *et. al.*, 2010). The accessions were collected from Wote region (Lower Midland).

3.1.4 Kwale County

Kwale County is located in the Coastal part of Kenya. It lies at an altitude of between 60 and 135 meters above sea level (Jaetzold *et. al.*, 2010). The County also lies at a latitude of - 4.1738 and a longitude of 39.4521 (GoK, 2013b) The average annual precipitation range from 1200mm at the coastal belt to 600mm .In the coastal lowlands, the average temperatures ranges from 25ºC to 26.6ºC in Shimba Hills, and from 24.6ºC to 27.5ºC in the hinterland (Jaetzold, 2010; GoK, 2013b). The County is divided into several agro-

ecological zones (Jaetzold *et. al.*, 2010). This study targeted agricultural potential areas which are the wet Coastal uplands commonly known as Shimba Hills, the hot and humid coastal plain where crop production and fishing activities predominate (including areas near the shoreline) and the sub-humid foot plateau including areas bordering the elevated Nyika Plateau such as Matuga and Kikoneni (MoALF, 2016d). Kwale's soils vary, from loamy to sandy with basement rocks (GoK, 2013b). Cucurbit production in Kwale County is majorly for export (HCDA, 2014).

3.1.5 Kilifi County

Kwale County lies at a latitude of -3.6667 and a longitude of 39.7500 (Jaetzold *et al.*, 2010). Four agro-ecological zones can be identified namely: Coastal Lowland (CL) zone 3, 4, 5 and 6 (Jaetzold *et al*., 2010). The CL3 has a precipitation of 1,300 mm per annum and mean annual temperature of 24^{o}C (Jaetzold *et. al.*, 2010). The altitude ranges from 1-450 m above sea level (Jaetzold *et. al.*, 2010). The CL4, has an average precipitation of 900 mm and annual mean temperature of 24^{o}C. The CL5 is of lower agricultural potential with precipitation of 700-900 mm and temperatures of 25.2 - 27.0^{o}C (Jaetzold *et. al.*, 2010). The CL6 lies in an altitude of 90-300 m ASL with a mean annual temperature of 27^{o}C and annual precipitation of 350 -700 mm (MoALF, 2016e). The soil ranges from loamy to sandy soil (Jaetzold *et al.*, 2010). Cucurbit production in Kilifi County is majorly for export (HCDA, 2014).

3.1.6 Migori County

The county has an altitude varying between 1140 to 4625 m above the sea level. It also lies at a latitude of -0.6667 and a longitude of 34.883 (Jaetzold *et. al.*, 2010). The area experiences mean average temperature ranging from minimum of 24^{o}C to maximum of 31^{o}C, with high humidity and a potential evaporation of 1800 to 2000 mm per year (Jaetzold *et al.*, 2010). Six agro-ecological zones have been identified in the county ranging from to LM 1-5 covering parts of Nyatike, Rongo and Migori sub-counties to UM 1-4 covering Kuria East and West, Rongo, Kehancha and Ntimaru sub-counties (MoALF, 2016f). Agricultural activities in the County vary with the agro-ecological zones. Migori soils are majorly well drained and tend to be loamy (Jaetzold *et al.*, 2010).

Melon production is majorly for local consumption. The study covered Rongo (LM4), Migori and Kehancha (UM 1-4).

3.1.7 Machakos County

Machakos County is located in the Eastern Kenya region. It lies at a latitude of -1.5167 and a longitude of 37.2667 (Jaetzold *et. al.*, 2010).The County is largely semi-arid, receiving a mean annual rainfall of about 500 mm with variations depending on the altitude (Jaetzold *et. al.*, 2010). Temperatures range from 18 to 29°C (Jaetzold *et al.*, 2010). The county is categorized into five agro-ecological zones based on the potential crop production suitability (Jaetzold *et al.*, 2010). The UM 2-3 is mostly suitable for maize, beans, dairy and coffee while UM 5-6 is suitable for ranching (Jaetzold *et. al.*, 2010). The LM 3-5 is suitable for dairy keeping, beans, maize, pigeon peas, cow peas, mangoes and indigenous chicken and is found in Matungulu, Mwala, Masinga, and Yatta (Jaetzold *et. al.*, 2010). The study covered mainly the UM 2-3 around Machakos and Kangundo areas.

3.1.8 Muranga County

The county is located at the Central region of Kenya with a latitude of -0.7167 and a longitude of 37.1500 (Jaetzold *et. al.*, 2010). The average annual temperature of the area is 20.0^{o}C. The average annual precipitation is 1195 mm (Jaetzold *et. al.*, 2010). The county lies between 914 m above sea level in the East and 3,353 m above sea level along the slopes of the Aberdare Mountains in the West (Jaetzold *et. al.*, 2010). The county is divided into six agro-ecological zones. The agro-ecological zone one consists of the highest potential zones where forestry, tea and tourism industry form the most important economic activities (Jaetzold *et. al.*, 2010). Agro-ecological zones two and three are the lowlands east of Aberdares and are generally suitable for both coffee and dairy farming (Jaetzold *et. al.*, 2010). The flatter area of Makuyu division of Maragwa constituency is characterized by arid and semi-arid conditions and lies in agro-ecological zones 4, 5 and 6 (Jaetzold *et. al.*, 2010). This is where the study covered. In these zones, coffee and pineapple plantations thrive by irrigation (Jaetzold *et al*., 2010).

3.1.9 Homa Bay County

The County of Homa Bay is located in south western Kenya. The county lies at a latitude of -0.68333 and a longitude of 34.45 (Jaetzold *et. al.*, 2010). The temperatures in the County range from 17.1°C to 34.8°C averaging 22.5°C (GoK, 2013c). The average annual rainfall is 1226 mm. The County is divided into several agro-ecological zone, mainly upper midlands (UM1), (UM3), (UM4) and lower midlands (LM2), (LM3), (LM4) and (LM5) (Jaetzold *et. al.*, 2010). Agricultural activities in the County vary with the agro-ecological zones. The area supports livestock rearing and millet growing (Jaetzold *et al.*, 2010). Agriculture is the leading income contributor to the households and it plays a crucial role to food and nutrition security in the County (Jaetzold *et. al.*, 2010).

3.1.10 Tharaka-Nithi County

Tharaka-Nithi County is located in the Eastern part of Kenya. The county lies between latitudes 000 07' and 000 26' South and between longitudes 370 19' and 370 46' East (Jaetzold *et. al.*, 2010). The County has two main ecological zones. The highlands (upper zone) comprise of Maara that receives adequate rainfall for agriculture (Jaetzold *et. al.*, 2010). The semi-arid zone (lower zone) covers Tharaka North and Tharaka South sub counties and receives less than 700 mm of rainfall per annum, making it largely suitable for livestock rather than crop production. Tharaka Nithi is generally a low land, with an altitude ranging between 250 and 1500 m (Jaetzold *et. al.*, 2010). The County has mean annual temperatures that range from below 21°C in the west to above 25°C in the east, this variation being primarily due to an east to west pattern of rising altitude (Jaetzold *et. al.*, 2010). Most of the western part of the county receives average rainfall of 1000- 1250 mm annually while the eastern part of the county receives an average of 750-1000 mm annually, except for a small south eastern corridor where rainfall is 500 - 750 mm. The forest area receives as much as 2200 mm annually (Jaetzold *et al.*, 2010).

3.1.11 Kisii County

Kisii County is located in western part of Kenya. The county lies at a latitude of -0.6667 and a longitude of 34.7500 (Jaetzold *et al.*, 2010). The county can be divided into three

agro-ecological zones comprising of 75% UM, 20% LH and 5% LM. The study covered the areas of Nyakoe. The maximum temperatures in the county range between 21°C – 30°C while the minimum temperatures range between 15°C – 20°C (Jaetzold *et. al.*, 2010). The average temperature in Kisii is 19.6°C. In a year, the average rainfall is 1922 mm (Jaetzold *et al.,* 2010).

3.1.12 Narok County

Narok County is situated in Kenya along the Great Rift Valley. The county between a latitude of -1.0833 and a longitude of 35.8667 (Jaetzold *et al.,* 2010). Narok County has an elevation of 1827m above sea level with the soils being majorly sandy loam (Jaetzold *et al.,* 2010). The County covers an area of 17, 944 km^2 and has a population of 850,920. The temperature range is 12ºC to 28ºC and the average rainfall range of 500 to 1,800 mm per annum (Jaetzold *et. al.*, 2010). The samples were obtained from Mulot area.

3.2 Experimental Materials

Nineteen accessions of mature horned melon fruits were collected from the wild and farmers' fields from selected counties in Kenya where the crop is grown. These counties include Meru, Embu, Makueni, Kisii, Homabay, Muranga, Narok, Machakos, Tharaka Nithi, Kwale and Migori (Figure 3.1 and Table 3.1). The collections comprised of local landraces and wild types.

Figure 3.1: Map of Kenya Showing the Counties

Source**:** MoLPP, 2019

Table 3.1: List of Horned Melon Accessions Evaluated in the Study

S/No.	Accession Code	County	Place of Collection	AEZ	GPS Coordinates
1	ACC1	Tharaka-Nithi	Kathwana	UM	0.327201S, 37.866059E
2	ACC2	Meru	Meru	UH	0.051541N, 37.645855E
3	ACC3	Embu	Siakago	LM	0.577330S, 37.640544E
4	ACC4	Murang'a	Maragua	UM	0.799959S, 37.133016E
5	ACC5	Tharaka-Nithi	Chuka	UH	0.331004S, 37.647958E
6	ACC6	Migori	Kehancha	UM	1.193604S, 34.615860E
7	ACC7	Narok	Narok	LH	1.085049S, 35.877356E
8	ACC8	Embu	Kianjokoma	UM	0.395741S, 37.503827E
9	ACC9	Machakos	Kangundo	LM	1.299215S, 37.350726E
10	ACC10	Kwale	Kwale	LH	4.181473S, 39.460144E
11	ACC11	Migori	Rongo	LM	0.746204S, 34.595284E
12	ACC12	Machakos	Machakos	LM	1.528227S, 37.263005E
13	ACC13	Migori	Migori	UM	1.070804S, 34.472522E
14	ACC14	Meru	Mitunguu	UH	0.108490S, 37.784815E
15	ACC15	Makueni	Wote	LM	1.788249S, 37.633152E
16	ACC16	Embu	Kiambere	LM	0.684613S, 37.792102E
17	ACC17	Embu	Embu	UM	0.487726S, 37.458003E
18	ACC18	Kisii	Nyakoe	LM	0.627900S, 34.762945E
19	ACC19	Homabay	Oyugis	LM	0.507982S, 34.737482E

3.3 Description of the Study Site

The field experiment was carried out at the University of Embu Research Farm in Embu County, Kenya. The site is located on latitude 0º 31' 52.03" N and longitude 37º 27' 2.20" E at an elevation of 1480 m above sea level (Kenya Information Guide, 2015). The average annual rainfall is 1252 mm and is received in two distinct rainy seasons; the long rains (mid-March to September) with an average rainfall of 650 mm and the short rains (mid- October to February) with an average of 450 mm (Kenya Information Guide, 2015). The area has a mean annual temperature of 19.5ºC, a mean maximum of 25ºC, and a mean minimum of 14.1ºC (Jaetzold *et al*., 2006). The mean annual potential evaporation is 1422 mm while mean annual evapo-transpiration is 950 mm (Jaetzold *et al*., 2006). The soils are mainly hemic nitisols derived from basic volcanic rocks. They are deep, highly weathered with friable clay texture and moderate to high inherent fertility (FAO, 2011). Most farmers rely on production of crops like maize and horticultural crops such as tomatoes (Munene *et al*., 2018).

3.4 Preparation of Experimental Materials

The ripened fruits were collected and transported in well labelled paper bags to the University of Embu. The fruits were cut open with a sharp knife and the pulp carefully scooped out using a clean spatula. The obtained seeds were separately fermented to remove the jelly-like substance and to soften the seed coat (Mccormack, 2005). This was done in plastic containers using pure water for three days and then sun-dried (Aliero & Gumi, 2012). The same plant material was used for both seasons.

3.5 Experimental Design and Layout

The field experiment was laid out in a Randomized Complete Block Design with three replications. The nineteen different accessions were used as treatments and were allocated experimental plots measuring 3 m by 3m. A one-meter-wide alley was provided between plots to avoid any interference with the plants during data collection and crop husbandry. Three seeds were planted per hole at a spacing of 1 m by 1 m and later thinned to one seedling one week after germination (Aliero & Gumi, 2012). Well decomposed farm yard manure (15^{o} C - 20^{o} C) and TSP fertilizer were applied in the planting holes before sowing at the recommended rates of 30 t/ha and 200 Kg/ha, respectively (Weng, 2010). Each plot comprised of five plants that were planted in a zigzag pattern to ensure and data was collected from four tagged plants. Two rows of the Embu accession were used as guard rows around the experimental field (Gichimu *et al*. (2009a). Other agronomic practices including irrigation, pests and weeds control were done uniformly in all the plots whenever necessary. Weeding was manually done using a jembe. Pests like the red spider mites were controlled using Bazooka $^{(R)}$ 18EC at 10ml/20L (Aliero & Gumi, 2012).The study was carried out in two seasons from October 2018 to January 2019 and from March to July 2019. The first season was conducted under rain-fed conditions while for the second season, there was supplementary irrigation due to the precipitation deficit experienced in the whole country. The weather condition during the two seasons has been presented in appendix 8.

3.6 Data Collection

3.6.1 Agro-Morphological Characterization

Morphological data were recorded from four selected and tagged plants in each accession in each replicate. Tagging was done on the third week after planting where plants with good health and uniform growth stage were considered. Characterization was based on IPGRI (2003) descriptors for melons (appendix 1) which was also used by Jarret and Griffin (2007) and Gichimu *et al*. (2009a). Qualitative parameters included growth habit, rind colour, flesh colour, fruit shape, seed shape and seed colour. Quantitative parameters included rind thickness, number of seeds per plant, main vine length, branch number per plant, fruit number per plant and average fruit weight. Data scoring for each character was done on the same day for each accession from the third week till 50% flowering to avoid the differences in development stages of growth (Jarret & Griffin, 2007). Other agronomic parameters included percentage germination, days to emergence, days to female and male flowering, days to maturity and resistance to pests and diseases.

3.6.1 Determination of Nutritional Composition of Horned Melon Accessions

At physiological maturity, the fruits were harvested when the outer flesh changed from dark green to pale yellow (Aliero & Gumi, 2012). The fruits were then washed and ground into sample pastes. The paste was put in plastic containers and appropriately labelled. The sample paste for each accession was divided into triplicate then their nutrient component determined (Aliero & Gumi, 2012).

3.6.1.1 Determination of Moisture and Sugar Content

Moisture content of fruit samples were determined by oven drying method (Nerdy, 2018). Moisture content was obtained by drying the fresh fruit samples to a constant weight in a thermostatically controlled oven at 105^{o}C as described in appendix 2. The moisture content was calculated on wet-weight basis using the following formula:

$$\text{Moisture content (\%)} = \frac{W2 - W3 \times 100}{W2-W1}$$

Where,

W1 = weight of container with lid;

W2 = weight of container with lid and sample before drying; and

W3 = weight of container with lid and sample after drying.

Sugar content was determined by use of brix refractometer (Wilberforce, 2016) as described in appendix 3.

3.6.1.2 Quantification of Ascorbic acid

Ascorbic acid or Vitamin C was quantified by titrating the fruit sample against phenol indo-2, 6- Dichlorophenol (DPIP) as described in appendix 4. Diluted juice was pipetted into a 100 ml volumetric flask, then 25 mL of 20% metaphosphoric acid was added then diluted to the required quantity. Ten (10) ml of fruit juice was pipetted in a small flask and 2.5 ml of acetone added. Indophenol solution was used in titration until a faint pink colour persisted for 15 seconds (Tareen *et al*., 2016). The results were expressed as mg/100g dry weight.

3.6.1.3 Quantification of mineral elements

The mineral elements were determined by atomic absorption spectrophotometry and flame photometry. Each of the fruit samples was accurately weighed in 2.5 g and separately put into crucibles and placed inside a muffle furnace at 550^{o}C for 5 hours for ashing. The ash was dissolved with 20 ml of 0.1M HNO_3 solution and made to a final volume of 100 ml with deionized water in volumetric standard flask. Absorbance was measured on an atomic absorption spectrophotometry for Fe and P and flame photometry for K and Na according to the wavelength of each mineral (Jenway PFP7). The concentration of iron and phosphorus minerals in the sample was determined by regression line equation obtained from the determination of the linearity standard series solution of each mineral.

3.7 Data Analysis

In order to estimate the morphological diversity between the accessions, qualitative and quantitative data was organized into a matrix and subjected to cluster analysis using XLSTAT Version 2019. Estimates of similarity among the phenotypes were calculated using dissimilarity units and expressed as Euclidean genetic distance (Vaz *et al*., 2017). Dissimilarity indices were used to generate a dendrogram using the unweighted pair

group method with arithmetic average (UPGMA). Truncation was performed based on the classes' diversity (Vaz *et al.*, 2017). Principal Component Analysis (PCA) was used to analyze the contribution of the variables to the total variation observed between the nineteen horned melon accessions.

Agronomic and nutritional data was analyzed using SAS software version 9.4. Agronomic variables were subjected to ANOVA at 5% level of significance to test for the significant differences between accessions. Separation of means was done for all parameters using SNK at 95% level of confidence. Pearson correlation coefficients were carried to determine the relationship between the growth and yield characteristics.

CHAPTER FOUR
RESULTS

4.1 Agro-Morphological Diversity

4.1.1 Qualitative Traits

The qualitative characters that were scored on the 19 horned melon accessions were growth habit, leaf blade, leaf shape, flower biology, corolla colour, fruit shape, predominant rind colour, design produced by secondary skin colour, skin stripe colour, presence of grooves on the fruit, flesh colour, seed shape and seed colour. There was no variation in all the qualitative traits except the fruit shape, predominant rind colour and seed shape (Table 4.1). For the fruit shape, 74% of the accessions were elliptically shaped while 26% were cylindrically shaped. The cylindrical ones were from Maragua, Meru, Migori, Oyugis and Rongo. For the rind colour, 63.84% were light green while 36.16% were dark green. The dark green ones consisted of accessions from Kathwana, Maragua, Chuka, Kianjokoma, Migori, Kiambere and Oyugis. For the seed shape, 63.16% were elliptically shaped while 36.84% had pinonette shape. The pinonette shaped ones included accessions from Embu, Siakago, Chuka, Kathwana, Mitunguu, Machakos and Kwale while the rest of the accessions were elliptically shaped.

There was no variation in all the other qualitative traits namely growth habit, leaf blade, leaf shape, flower biology, corolla colour, design produced by secondary skin colour, presence of grooves on the fruit, flesh colour and seed colour. The leaves had 3-palmately shallow lobed blade. Both male and female flowers were yellow in colour for all the accessions. The fruit had a mixture of both dotted and stripe skin design with green background and grooves present in the whole fruit. The flesh colour was green with white seeds. All the accessions were runners with a main vine that was highly branched.

Table 4.1: Variation in Qualitative Variables of the 19 Horned Melon Accessions

S/No.	Accessions	Leaf shape	Growth habit	Rind colour	Rind Pattern	Flesh colour	Fruit shape	Seed shape	Seed colour	Grooves	Leaf Blade	Petal Colour
1.	Kathwana	Entire	Runner	Dark green	Mixed	Green	Elliptical	Pinonette	White	Whole	Shallow	Deep yellow
2.	Meru	Entire	Runner	Light green	Mixed	Green	Cylindrical	Elliptical	White	Whole	Shallow	Deep yellow
3.	Siakago	Entire	Runner	Light green	Mixed	Green	Elliptical	Pinonette	White	Whole	Shallow	Deep yellow
4.	Maragwa	Entire	Runner	Dark green	Mixed	Green	Cylindrical	Elliptical	White	Whole	Shallow	Deep yellow
5.	Chuka	Entire	Runner	Dark green	Mixed	Green	Elliptical	Pinonette	White	Whole	Shallow	Deep yellow
6.	Kehancha	Entire	Runner	Light green	Mixed	Green	Elliptical	Elliptical	White	Whole	Shallow	Deep yellow
7.	Narok	Entire	Runner	Light green	Mixed	Green	Elliptical	Elliptical	White	Whole	Shallow	Deep yellow
8.	Kianjokoma	Entire	Runner	Dark green	Mixed	Green	Elliptical	Elliptical	White	Whole	Shallow	Deep yellow
9.	Kangundo	Entire	Runner	Light green	Mixed	Green	Elliptical	Elliptical	White	Whole	Shallow	Deep yellow
10.	Kwale	Entire	Runner	Light green	Mixed	Green	Elliptical	Pinonette	White	Whole	Shallow	Deep yellow
11.	Rongo	Entire	Runner	Light green	Mixed	Green	Cylindrical	Elliptical	White	Whole	Shallow	Deep yellow
12.	Machakos	Entire	Runner	Light green	Mixed	Green	Elliptical	Pinonette	White	Whole	Shallow	Deep yellow
13.	Migori	Entire	Runner	Dark green	Mixed	Green	Cylindrical	Elliptical	White	Whole	Shallow	Deep yellow
14.	Mitunguu	Entire	Runner	Light green	Mixed	Green	Elliptical	Pinonette	White	Whole	Shallow	Deep yellow
15.	Wote	Entire	Runner	Light green	Mixed	Green	Elliptical	Elliptical	White	Whole	Shallow	Deep yellow
16.	Kiambere	Entire	Runner	Dark green	Mixed	Green	Elliptical	Elliptical	White	Whole	Shallow	Deep yellow
17.	Embu	Entire	Runner	Light green	Mixed	Green	Elliptical	Pinonette	White	Whole	Shallow	Deep yellow
18.	Nyakoe	Entire	Runner	Light green	Mixed	Green	Elliptical	Elliptical	White	Whole	Shallow	Deep yellow
19.	Oyugis	Entire	Runner	Dark green	Mixed	Green	Cylindrical	Elliptical	White	Whole	Shallow	Deep yellow

4.1.2 Quantitative Traits

Quantitative characters that were evaluated include vine length, number of branches on the main vine, fruit number, fruit weight, seed size and rind thickness. There were highly significant ($p<0.0001$) differences between accessions for seed size and rind thickness in both seasons (Table 4.2 and 4.3). The different accessions also varied significantly in fruit number in season 1 ($p<0.004$) and for the combined season analysis ($p<0.001$) as shown in Table 4.2 and Table 4.4 respectively. The means for all the other quantitative variables were significantly ($p>0.05$) different among accessions. Siakago accession was leading in fruit number (20) in the first season but reduced significantly to less than 10 in the second season. The Rongo accession recorded the highest average number (17) of fruits for the combined seasons. All the accessions recorded lower yields in the second season as compared to the first season except the Meru accession. Machakos and Nyakoe accessions consistently recorded the biggest and the smallest rind thickness respectively in both seasons (Tables 4.2 4.3 and Appendix 9). Seasonal variations were significant for some of the quantitative morphological variables like fruit number and rind thickness (data not shown). Season by accession interactions were not significant for all the quantitative variables indicating that different variables responded in a similar way to different production seasons (Appendix 9).

Table 4.2: Variation in Quantitative Traits of Horned Melon Accessions for Season 1

Accessions	Main Vine Length (cm)	Branch Number	Fruit Number	Fruit Weight (g)	Seed Size (mm)	Rind Thickness (mm)
Kathwana	265.00	14.80	11.00^{ab}	226.33	4.00^{a}	4.18^{b}
Meru	260.67	12.83	10.67^{ab}	259.33	3.75^{abc}	4.17^{b}
Siakago	258.50	15.17	20.00^{a}	256.00	3.87^{ab}	3.86^{bcd}
Maragua	269.00	15.33	16.67^{ab}	246.00	4.10^{a}	3.54^{bcde}
Chuka	264.67	13.83	9.67^{ab}	194.67	3.46^{bcd}	3.03^{de}
Kehancha	254.83	17.50	11.00^{ab}	214.67	3.67^{abc}	4.17^{b}
Narok	238.83	14.83	11.00^{ab}	207.00	3.73^{abc}	3.38^{bcde}
Kianjokoma	255.00	12.33	11.67^{ab}	215.33	3.20^{d}	3.07^{de}
Kangundo	267.17	16.33	7.33^{b}	218.00	3.70^{abc}	4.03^{b}
Kwale	253.17	16.00	10.33^{ab}	227.67	4.00^{a}	3.04^{de}
Rongo	253.00	13.83	18.67^{a}	204.00	3.35^{cd}	3.64^{bcde}
Machakos	268.67	15.67	13.33^{ab}	195.00	3.98^{a}	5.30^{a}
Migori	239.33	15.00	15.00^{ab}	196.67	3.44^{bcd}	3.03^{de}
Mitunguu	267.67	15.00	12.33^{ab}	214.33	4.07^{a}	3.91^{bc}
Wote	280.83	15.93	18.33^{a}	207.00	3.71^{abc}	3.58^{bcde}
Kiambere	251.00	14.33	13.67^{ab}	214.67	3.17^{d}	3.11^{de}
Embu	267.17	14.50	11.33^{ab}	230.67	3.86^{ab}	3.60^{bcde}
Nyakoe	249.67	15.33	15.33^{ab}	226.00	4.05^{a}	2.94^{e}
Oyugis	256.33	14.50	9.33^{ab}	259.33	3.45^{bcd}	3.23^{cde}
P value	0.916^{NS}	0.873^{NS}	**0.004**	0.442^{NS}	**< 0.0001**	**< 0.0001**
SE	14.350	1.543	2.097	20.379	0.107	0.172

Means followed by the same letter are not significantly different based on Students Newman's Keuls (SNK) test at $p \leq 0.05$. NS = Not Significant; SE = Standard Error

Table 4.3: Variation in Quantitative Traits of Horned Melon Accessions for Season 2

Accessions	Main Vine Length (cm)	Branch Number	Fruit Number	Fruit Weight (g)	Seed Size (mm)	Rind Thickness (mm)
Kathwana	258.67	16.17	9.00	226.32	3.82^{ab}	4.30^{b}
Meru	240.67	14.67	15.67	259.33	3.54^{abcd}	4.40^{b}
Siakago	240.50	16.83	9.75	256.00	3.71^{abc}	4.02^{bcd}
Maragua	259.33	15.17	12.94	246.00	3.95^{a}	3.69^{bcd}
Chuka	252.67	15.50	12.39	194.67	3.67^{bcd}	3.21^{d}
Kehancha	251.83	15.67	10.94	214.67	3.52^{abcd}	4.34^{b}
Narok	234.67	13.83	13.36	207.00	3.46^{abcd}	3.56^{bcd}
Kianjokoma	243.33	15.33	9.92	215.33	3.23^{cd}	3.25^{d}
Kangundo	259.33	15.67	7.50	218.00	3.62^{abcd}	4.21^{bc}
Kwale	238.50	15.33	8.67	227.67	3.75^{abc}	3.30^{d}
Rongo	256.50	15.67	14.33	204.00	3.28^{bcd}	3.80^{bcd}
Machakos	267.17	15.50	12.36	195.00	3.82^{ab}	5.45^{a}
Migori	242.33	14.67	11.75	196.67	3.29^{bcd}	3.22^{d}
Mitunguu	255.50	15.00	12.33	214.67	4.96^{a}	3.86^{bcd}
Wote	273.33	16.50	13.81	207.00	3.59^{abcd}	3.73^{bcd}
Kiambere	257.33	14.33	11.00	214.67	3.12^{d}	3.28^{d}
Embu	262.67	15.50	10.58	230.67	3.44^{abcd}	3.76^{bcd}
Nyakoe	254.33	16.50	12.89	226.00	3.92^{a}	3.08^{d}
Oyugis	248.33	14.33	8.44	259.33	3.59^{abcd}	3.39^{cd}
P value	0.877^{NS}	0.990^{NS}	0.375^{NS}	0.442^{NS}	**< 0.0001**	**< 0.0001**
SE	13.418	1.338	2.082	20.379	0.0389	0.190

Means followed by the same letter are not significantly different based on Students Newman's Keuls (SNK) test at $p \leq 0.05$. NS = Not Significant; SE = Standard Error

Table 4.4: Variation in Quantitative Traits of Horned Melon Accessions for the Two Seasons Combined

Accessions	Main Vine Length (cm)	Branch Number	Fruit Number	Fruit Weight (g)	Seed Size (mm)	Rind Thickness (mm)
Kathwana	261.83	15.48	10.00^{abc}	226.33	3.91^{ab}	4.24^{b}
Meru	250.58	13.75	13.17^{abc}	259.33	3.65^{bcd}	4.28^{b}
Siakago	249.42	16.00	14.88^{abc}	256.00	3.79^{abc}	3.94^{bcd}
Maragua	264.17	15.25	14.81^{abc}	246.00	4.02^{a}	3.61^{cde}
Chuka	258.67	14.67	11.03^{abc}	194.67	3.41^{def}	3.12^{ef}
Kehancha	253.33	16.58	10.97^{abc}	214.67	3.59^{cde}	4.26^{b}
Narok	236.75	14.33	12.18^{abc}	207.00	3.60^{bcde}	3.46^{def}
Kianjokoma	249.17	13.83	10.79^{abc}	215.33	3.22^{f}	3.16^{ef}
Kangundo	263.25	16.00	7.41^{c}	218.00	3.66^{bcd}	4.12^{bc}
Kwale	245.83	15.67	9.50^{abc}	227.67	3.88^{ab}	3.19^{ef}
Rongo	254.75	14.75	16.50^{a}	204.00	3.32^{ef}	3.72^{cde}
Machakos	267.92	15.58	12.85^{abc}	195.00	3.90^{ab}	5.37^{a}
Migori	240.83	14.83	13.38^{abc}	196.67	3.36^{def}	3.12^{ef}
Mitunguu	261.58	15.00	12.33^{abc}	214.33	4.01^{a}	3.89^{bcd}
Wote	277.08	16.21	16.07^{ab}	207.00	3.65^{bcd}	3.66^{cde}
Kiambere	254.17	14.88	12.33^{abc}	214.67	3.14^{f}	3.20^{ef}
Embu	265.25	15.00	10.96^{abc}	230.67	3.65^{bcd}	3.68^{cde}
Nyakoe	252.00	15.91	14.11^{abc}	226.00	3.99^{a}	3.01^{f}
Oyugis	252.42	14.42	8.88^{bc}	259.33	3.52^{cde}	3.31^{ef}
P value	0.949^{NS}	0.987^{NS}	**0.001**	0.070^{NS}	**<0.0001**	**<0.0001**
SE	9.823	1.021	1.477	14.410	0.0298	0.128

Means followed by the same letter are not significantly different based on Students Newman's Keuls (SNK) test at p≤ 0.05. NS = Not Significant; SE = Standard Error

4.1.3 Agronomic Traits

Agronomic parameters that were evaluated included percentage germination, days to emergence, days to male and female flowering and days to maturity. There were highly significant (P<0.001) differences in all agronomic traits as shown in Tables 4.5 (season 1), 4.6 (season 2), 4.7 and Appendix 9 (combined seasons). The accessions from Kathwana, Siakago, Kangundo and Embu accessions recorded the highest percentage germination of 100% for both seasons. Kehancha accession consistently recorded the lowest germination percentage of 50.33% and 58.33% in first and second season respectively. For days to emergence, the Meru and Kathwana accessions took the shortest (8 days) and longest (12 days) to emerge respectively. Across the two seasons, Kehancha accession recorded the shortest time (59 days) to produce the male flowers while the Rongo accession recorded the longest time (74 days). Kehancha accession again took the shortest time (62 days) to produce the female flowers while the Kangundo accession took the longest time (75 days).

On days to maturity, Kehancha accession took the shortest maturity period of 102 days while Oyugis accession took the longest period of 122 days. Seasonal variations were significant for percent germination ($p<0.031$), days to male flowering ($p<0.0001$) and days to female flowering ($p<0.0001$). Season by accession interactions were also significant for days to emergence ($p<0.001$), days to male flowering ($p<0.0001$) and days to female flowering ($p<0.0001$) indicating that these variables responded differently to different seasons (Appendix 9).

Table 4.5: Variation in Agronomic Traits of Horned Melon Accessions for Season 1

Accessions	Percent Germination	Days to Emergence	Days to Male Flowering	Days to Female Flowering	Days to Maturity
Kathwana	100^{a}	11.67^{a}	66.33^{cde}	69.33^{bc}	100.67^{cd}
Meru	88.67^{a}	8.33^{d}	62.33^{de}	65.00^{c}	102.33^{cd}
Siakago	100^{a}	9.33^{bcd}	61.33^{de}	64.33^{c}	101.33^{cd}
Maragua	100^{a}	8.67^{cd}	63^{de}	66.00^{bc}	103.33^{cd}
Chuka	100^{a}	9.67^{bcd}	63^{de}	66.00^{bc}	103.67^{cd}
Kehancha	50.33^{b}	9.67^{bcd}	60^{e}	63.00^{c}	98^{d}
Narok	78^{ab}	9.67^{bcd}	60^{e}	69.67^{bc}	101^{cd}
Kianjokoma	100^{a}	8.67^{cd}	66.67^{cde}	69.33^{bc}	106^{bcd}
Kangundo	100^{a}	8.67^{cd}	60.67^{de}	63.63^{bc}	99^{d}
Kwale	100^{a}	9.67^{bcd}	66^{cde}	68.33^{bc}	100.33^{d}
Rongo	66.67^{ab}	10.33^{abc}	79^{ab}	82.00^{a}	111^{abc}
Machakos	94.33^{a}	10.67^{ab}	66.67^{cde}	68.67^{bc}	102.67^{cd}
Migori	89^{a}	10.33^{abc}	71.67^{ab}	73.33^{b}	116^{a}
Mitunguu	94.33^{a}	8.33^{d}	62^{de}	65.67^{bc}	102.67^{cd}
Wote	89^{a}	9.67^{bcd}	64^{cde}	67.33^{bc}	101.33^{cd}
Kiambere	94.33^{a}	10^{abcd}	66.67^{cde}	69.33^{bc}	107.33^{bcd}
Embu	100^{a}	10.33^{abc}	81.33^{a}	84.00^{a}	118.67^{a}
Nyakoe	100^{a}	11^{ab}	64^{cde}	65.67^{bc}	101.67
Oyugis	83.33^{ab}	10^{abcd}	68^{cd}	70.00^{bc}	119^{a}
P value	0.0004	0.0001	0.0001	0.0001	0.0001
S.E	2.2003	0.1342	0.1342	0.8000	0.9199

NB: Means followed by the same letter are not significantly different at p= 0.05.

Table 4.6: Variation in Agronomic Traits of Horned Melon Accessions for Season 2

Accessions	Percent Germination	Days to Emergence	Days to Male Flowering	Days to Female Flowering	Days to Maturity
Kathwana	100	10.33^{ab}	61^{bcd}	64.67^{abcde}	105.33^{e}
Meru	91.67	9.33^{b}	57.33^{d}	61.00^{cde}	107.67^{de}
Siakago	100	9.00^{b}	58.33^{cd}	61.00^{cde}	108.33^{de}
Maragua	83.33	9.33^{b}	61.67^{bcd}	64.67^{abcde}	109.67^{cde}
Chuka	91.67	9.67^{b}	59.33^{bcd}	61.67^{cde}	110.67^{cde}
Kehancha	58.32	9.67^{b}	57.00^{d}	59.67^{abcde}	105.33^{e}
Narok	66.67	9.67^{b}	58.33^{cd}	60.33^{de}	109.00^{de}
Kianjokoma	83.33	9.33^{b}	63.67^{abc}	66.67^{abc}	111.00^{cde}
Kangundo	100	9.00^{b}	58.33^{cd}	62.00^{bcde}	106.67^{de}
Kwale	91.67	9.67^{b}	59.67^{bcd}	64.00^{abcde}	108.00^{de}
Rongo	66.67	9.67^{b}	68^{a}	69.33^{a}	118.67^{abc}
Machakos	91.67	10.0^{ab}	60^{bcd}	62.67^{bcde}	109.33^{abcd}
Migori	75	11.33^{a}	62.33^{bcd}	65.00^{abcde}	125.00^{ab}
Mitunguu	100	9.00^{b}	59.33^{bcd}	62.00^{bcde}	111.67^{cde}
Wote	75	9.66^{b}	58.33^{cd}	61.67^{cde}	109.67^{cde}
Kiambere	91.67	10.0^{ab}	63.33^{abc}	66.00^{abcd}	115.67^{bcd}
Embu	100	9.00^{b}	63.00^{bcd}	64.67^{abcde}	124.67^{ab}
Nyakoe	91.67	9.60^{b}	59.67^{bcd}	63.33^{abcde}	111.67^{cde}
Oyugis	66.67	9.00^{b}	64^{ab}	67.67^{bcde}	125.33^{a}
P value	0.0038	0.0001	0.0001	0.0001	0.0001
S.E	2.3371	0.1089	0.4155	0.3989	0.9094

NB. Means followed by the same letter are not significantly different at p = 0.05

Table 4.7: Variation in Agronomic Traits of Horned Melon Accessions for the Two Seasons Combined

Accessions	Percent Germination	Days to Emergence	Days to Male Flowering	Days to Female flowering	Days to Maturity
Kathwana	100^{a}	11.00^{a}	63.67^{cdef}	66.17^{cdef}	103.00^{ef}
Meru	90.17^{abc}	8.83^{f}	59.83^{ef}	63.50^{def}	105.00^{ef}
Siakago	100^{a}	9.17^{cdef}	59.83^{ef}	63.00^{ef}	104.83^{ef}
Maragua	91.67^{abc}	9.00^{def}	62.33^{cdef}	65.33^{cdef}	106.50^{def}
Chuka	95.83^{ab}	9.67^{bcdef}	61.17^{cdef}	63.33^{def}	107.17^{def}
Kehancha	54.33^{d}	9.66^{bcdef}	58.50^{f}	61.83^{f}	101.67^{f}
Narok	72.33^{bcd}	9.67^{bcdef}	59.17^{ef}	62.33^{ef}	105.00^{ef}
Kianjokoma	91.67^{abc}	9.00^{adef}	65.17^{cdef}	67.83^{bcde}	108.50^{cde}
Kangundo	100^{a}	8.83^{f}	59.50^{ef}	74.67^{a}	102.83^{ef}
Kwale	95.83^{ab}	9.67^{bcdef}	63.50^{cdef}	66.00^{cdef}	104.17^{ef}
Rongo	66.67^{cd}	10.00^{abcde}	73.50^{a}	61.83^{f}	114.83^{bc}
Machakos	93.00^{ab}	10.33^{abc}	63.33^{cdef}	65.67^{cdef}	106.00^{def}
Migori	82.00^{abc}	10.83^{ab}	67.00^{bc}	69.00^{abcd}	120.50^{ab}
Mitunguu	97.17^{ab}	8.67^{f}	60.67^{def}	63.33^{def}	107.17^{def}
Wote	82.00^{abc}	9.66^{bcdef}	61.17^{cdef}	64.33^{cdef}	105.50^{def}
Kiambere	93.00^{ab}	10.00^{abcdef}	65.00^{cdef}	68.00^{bcde}	111.50^{cd}
Embu	100^{a}	10.16^{abcd}	72.17^{ab}	73.50^{ab}	121.67^{a}
Nyakoe	95.83^{ab}	10.33^{abc}	61.83^{cdef}	64.83^{cdef}	106.67^{def}
Oyugis	75.00^{abcd}	9.50^{cdef}	66.00^{cd}	69.50^{abc}	122.16^{a}
P value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
S.E	1.1680	0.8009	0.5155	0.4704	0.7281

NB: Means followed by the same letter are not significantly different at p= 0.05

4.1.4 Correlation Analysis between Quantitative Agro-Morphological Traits

Relation between the quantitative traits were expressed by a Pearson's correlation matrix shown in Tables 4.8 – 4.10. There was positive correlation between days to male and female flowering and days to maturity. For the first season, days to male flowering had strong positive correlation with days to female flowering (r = 0.988). Days to maturity also had a strong positive correlation with days to male flowering (r = 0.785) and days to female flowering (r = 0.810). For season two, there was a strong positive correlation between days to female flowering and days to male flowering (r = 0.972) and days to maturity (r = 0.645).

There was also strong correlation between days to male flowering and days to maturity (r = 0.676). When the two seasons were combined, the analysis showed strong positive correlation between days to male flowering and days to female flowering (r = 0.992) as

well as days to male flowering and days to maturity (r = 0.785). There was also strong correlation between days to female flowering and days to maturity (r = 0.809)

Table 4.8: Pearson's Correlation Coefficient for the Quantitative Traits of Horned Melon for Season 1

Variables	Vine Length						
Branch Number	0.146	**Branch Number**					
Fruit Number	0.045	0.026	**Fruit Number**				
Fruit Weight	0.101	-0.138	-0.001	**Fruit Weight**			
Days to Emergence	-0.191	0.161	0.129	-0.265	**Days to Emergence**		
DTMF	-0.060	-0.314	0.184	-0.125	0.432	**DTMF**	
DTFF	-0.101	-0.336	0.220	-0.066	0.417	**0.988***	**DTFF**
Days to Maturity	-0.202	-0.384	0.028	0.089	0.234	**0.785***	**0.810***

Key: Values in esterisks are different from 0 with significance level alpha=0.05. DTFF- Days to female flowering; DTMF- Days to male flowering

Table 4.9: Pearson's Correlation Coefficient for the Quantitative Traits of Horned Melon for Season 2

Variables	Vine Length						
Branch Number	0.402	**Branch Number**					
Fruit Number	0.085	-0.110	**Fruit Number**				
Fruit Weight	0.101	-0.138	-0.001	**Fruit Weight**			
Days to Emergence	0.058	-0.100	0.114	**0.507**	**Days to Emergence**		
DTMF	0.085	-0.194	-0.090	-0.074	0.212	**DTMF**	
DTFF	0.095	-0.174	-0.163	0.033	0.162	**0.972***	**DTFF**
Days to Maturity	0.020	-0.351	-0.029	0.002	0.332	**0.676***	**0.645***

Key: Values in esterisks are different from 0 with significance level alpha=0.05. DTFF- Days to female flowering; DTMF- Days to male flowering

Table 4.10: Pearson's Correlation Coefficient for the Quantitative Traits of Horned Melon for the Two Seasons combined

Variables	Vine Length						
Branch Number	0.398	**Branch Number**					
Fruit Number	0.112	0.054	**Fruit Number**				
Fruit Weight	-0.093	-0.090	-0.084	**Fruit Weight**			
Days to Emergence	-0.043	0.155	0.084	-0.392	**Days to Emergence**		
DTMF	0.037	-0.315	0.136	-0.114	0.434	**DTMF**	
DTFF	0.013	-0.351	0.150	-0.036	0.416	**0.992***	**DTFF**
Days to Maturity	-0.119	-0.423	0.020	0.046	0.301	**0.785***	**0.809***

Key: Values in esterisks are different from 0 with significance level alpha=0.05. DTFF- Days to female flowering; DTMF- Days to male flowering

4.1.5 Cluster Analysis using Agro-Morphological Traits

Agglomerative hierarchical clustering conducted using both quantitative and qualitative variables depicted high morphological diversity between the accessions (Figures 4.1 and 4.2). In both seasons, the dendrogram separated into 5 supported clusters. The diversity between classes was estimated at 63.82% in the first season and 68.84% in the second season thus the diversity within classes was 36.18% in the first season and 31.16% in the second season. In the first season, Kehancha and Embu accessions separated in their own supported singleton clusters while in the second season, Oyugis accession separated into a singleton supported cluster. There appeared to be close proximity between Maragua, Meru and Siakago accessions which grouped together in cluster 2 in both seasons. Rongo, Narok and Migori accessions also grouped together in cluster 3 in both seasons. The rest of the accessions grouped together in the biggest cluster of 10 members in season 1 (Figure 4.1) which separated further in season 2 to form two supported clusters with Wote, Chuka and Machakos in one cluster (Figure 4.2).

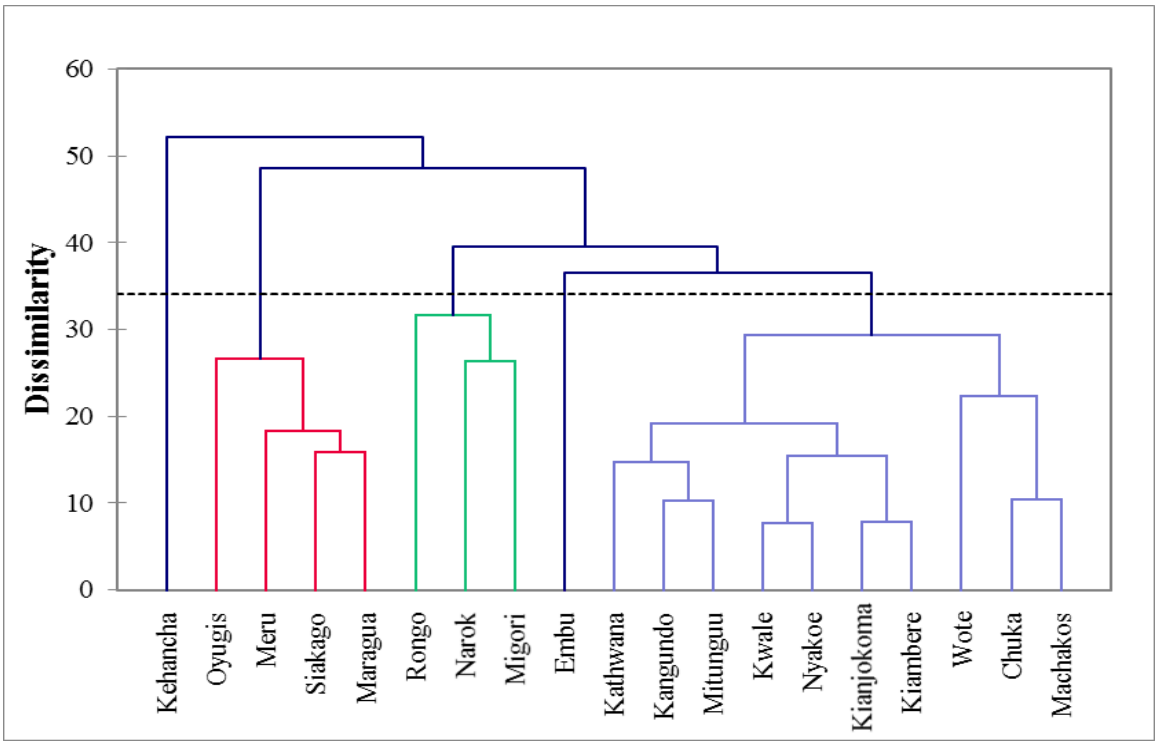

Figure 4.1: Cluster Dendrogram Illustrating Morphological Diversity between Horned Melon Accessions in Season 1

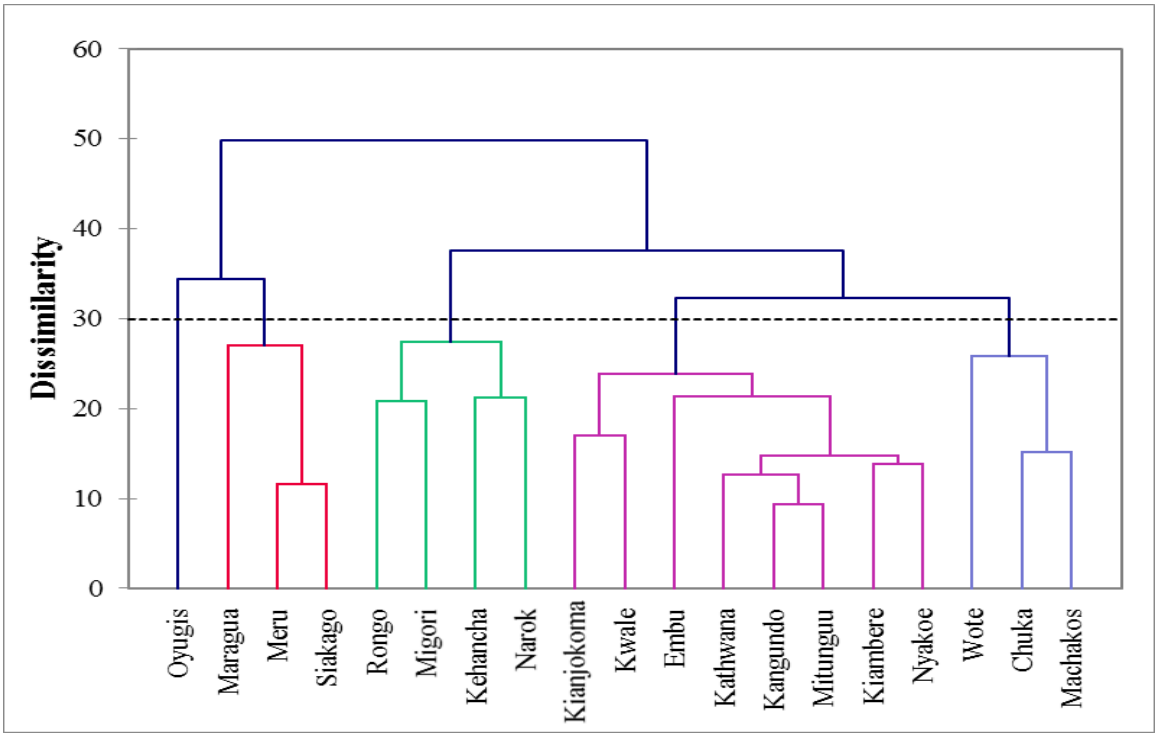

Figure 4.2:. Cluster Dendrogram Illustrating Morphological Diversity between Horned Melon Accessions in Season 2

4.1.6 Principal Component Analysis of Agro-Morphological Traits

Principal Component Analysis was used to describe contribution of specific variables to the observed variation among the horned melon accessions. The first three variability factors (F1, F2 and F3) explained 95.91% and 97.20% of the total variation in the first and second season respectively. The variables contributed differently to the observed variation with fruit weight and main vine length contributing the highest to F1 and F2 respectively in both seasons. On the other hand, days to male and female flowering and days to maturity had the highest contribution to F3 as shown in Table 4.11. The rest of the variables contributed minimally to the three principal factors. The correlation between the variables and the diversity factors F1 and F2 is shown Figure 4.4. Most of the variables portrayed diverse correlation with the factors in different seasons except fruit weight which was consistent over the two seasons. The proximity between accessions was further assessed through a two dimensional presentation which plotted the accessions at proximal distances based on their similarity (Figure 4.4).

Table 4.11: Percent Contribution of the Variables to the Total Variation

	Season 1			Season 2		
Variables	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**
Main Vine Length	0.466	**76.303**	**22.079**	3.134	**96.359**	0.213
Branch Number	0.006	0.111	0.106	0.000	0.112	0.173
Rind Colour	0.000	0.084	0.024	0.000	0.004	0.578
Fruit Shape	0.020	0.105	0.063	0.021	0.002	0.420
Seed Shape	0.000	0.173	0.104	0.001	0.012	0.124
Fruit Number	0.000	0.003	0.459	0.039	0.001	0.032
Days to Emergence	0.015	0.054	0.061	0.018	0.005	0.067
DTMF	0.147	5.462	**29.200**	0.011	0.066	9.685
DTFF	0.040	5.402	**22.652**	0.001	0.137	7.818
Days to Maturity	0.056	**11.796**	**25.232**	0.000	0.126	**80.709**
Fruit Weight	**99.249**	0.420	0.020	**96.773**	3.129	0.005
Seed Size	0.002	0.014	0.002	0.001	0.006	0.039
Rind Thickness	0.000	0.073	0.001	0.000	0.041	0.136
Eigenvalue	411.945	112.645	82.282	420.019	92.496	47.815
Variability (%)	65.105	17.803	13.004	72.859	16.045	8.294
Cumulative %	65.105	82.908	95.912	72.859	88.903	97.198

Key: DTFF- Days to female flowering; DTMF- Days to male flowering

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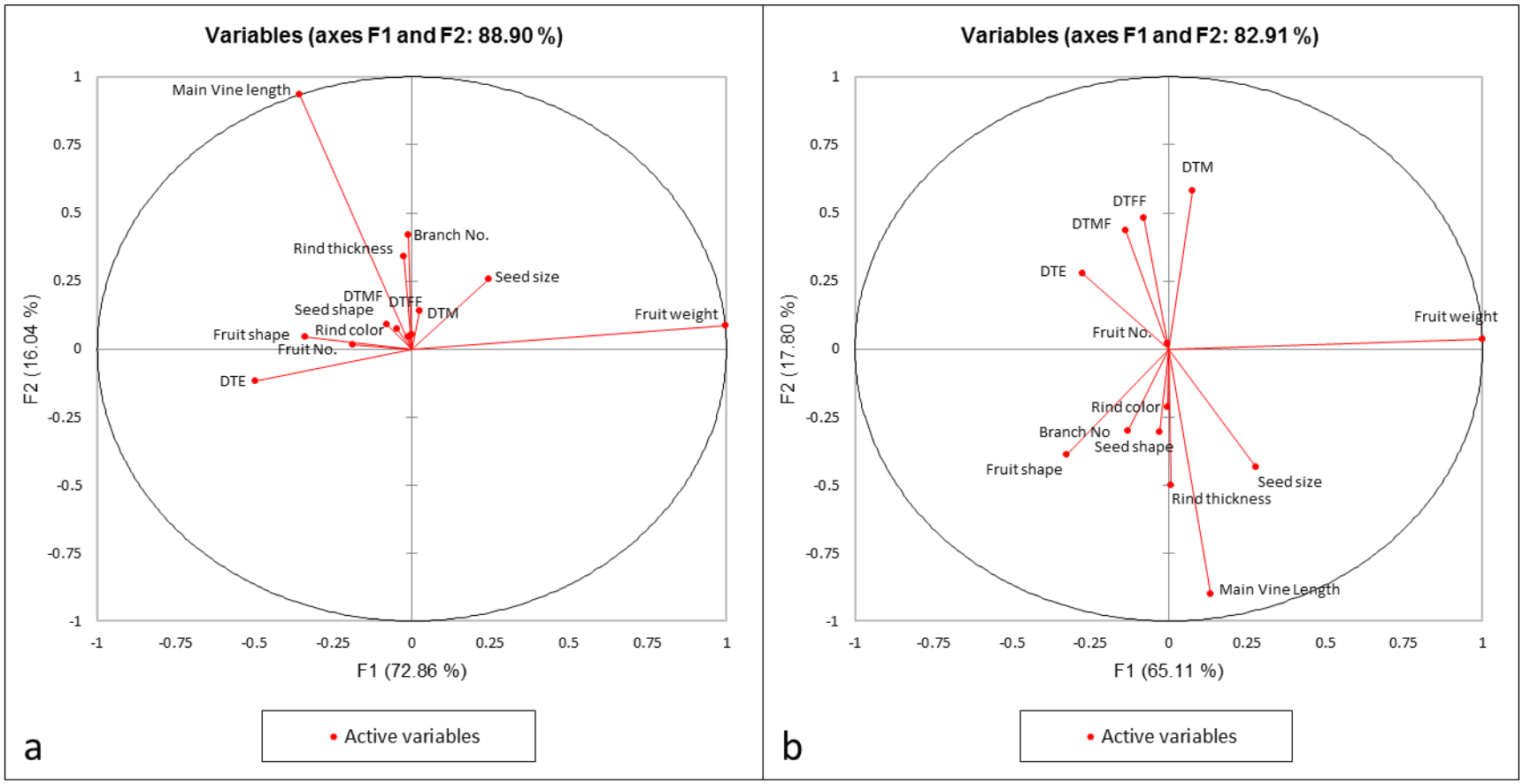


Figure 4.3: Correlation between the Variables and the Diversity Factors in Season 1 (a) and Season 2 (b)

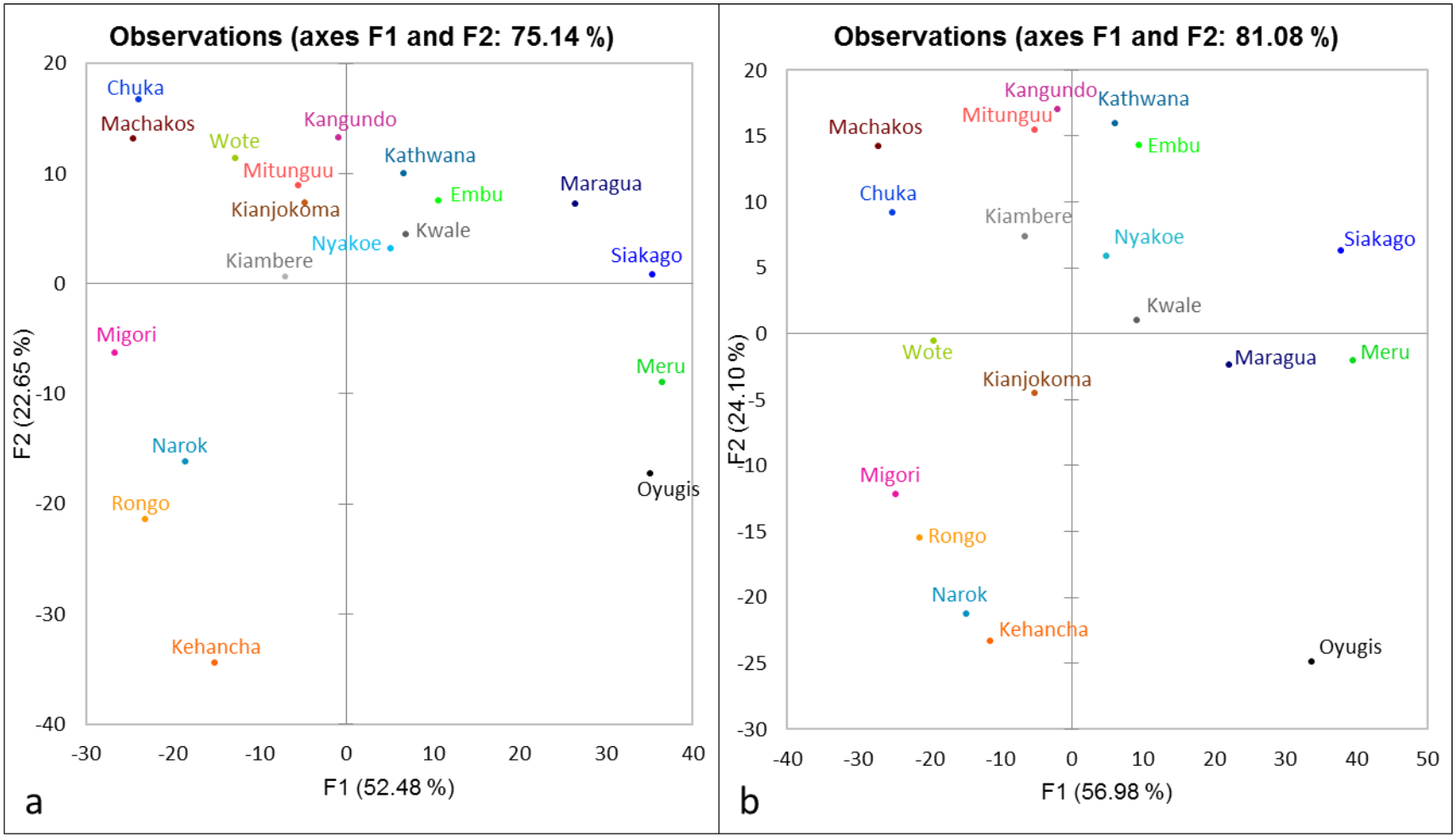


Figure 4.4: Two Dimension Plot Depicting the Proximity between Horned Melon Accessions in Season 1 (a) and Season 2 (b)

4.2 Proximate and Nutritional Composition of Horned Melon Accessions

Proximate and nutritional of the horned melon accessions are shown in Tables 4.12 (season 1), 4.13 (season 2), 4.14 and Appendix 9 (both seasons combined). In the first season, the accessions did not vary significantly in moisture content (Table 4.12) unlike in season 2 where there was highly significant difference in moisture content among the accessions ($p<0.0001$) as shown in Table 4.13. The Kiambere accession had the highest moisture content of 94.84% while Nyakoe accession had the lowest of moisture content of 91.52% in the second season. Combined season analysis, did not show any significant differences in moisture content between accessions (appendix 9). Sugar content was found to vary significantly ($p<0.0001$) between accessions. The Siakago and Meru accessions recording the highest (4.6% by mass) and lowest (2.14% by mass) sugar content, respectively, in season one (Table 4.12). The sugar content increased in the second season with Kehancha accession having the highest content of 5.09% by mass while Kwale accession had the lowest content of 3.07% by mass (Table 4.13). Kehancha accession maintained the highest sugar content of 4.39% by mass in the combined season analysis with Kangundo accession recording the lowest seasonal average of sugar content (3.04% by mass) as evident in Table 4.14.

The composition of the mineral contents in the fruits followed the order K > P >Na >Fe, with Potassium (K) being the most abundant mineral found in the fruits. In the first season, K content in the fruits ranged from 245.13 mg/100g recorded in Kathwana accession to 116.43 mg/100g recorded in Kiambere accession (Table 4.12). In the second season, K content was highest in Kangundo accession (254.30 mg/100g) while Kiambere accession had the lowest (167.70 mg/100g) (Table 4.13). Kangundo accession had the highest seasonal average of K content (249.52 mg/100g) while Kiambere maintained the lowest seasonal average of 142.07 mg/100g (Table 4.14). Phosphorus (P) content was highest in Migori accession (48.1mg/100g) and lowest in Kangundo accession (8.76 mg/100g) in season 1 (Table 4.12). In season 2, there was a general reduction in P content with Meru accession recording the highest content of 41.25mg/100g while the lowest content of 8.71 mg/100g was recorded by Machakos accession (Table 4.13). On seasonal

average, Migori accession had the highest P content of 40.49 mg/100g while Machakos had the lowest content of 8.88 mg/100g (Table 4.14).

Significant ($P<0.05$) variations in Sodium (Na) content were also recorded among accessions in both seasons. The Rongo and Wote accessions recorded the highest Na content of 2.28 mg/100g and 2.36 mg/100g in the first (Table 4.12) and second (Table 4.13) season respectively. Siakago accession consistently recorded the lowest content of 1.13mg/100g and 1.07 mg/100g in the first (Table 4.12) and second (Table 4.13) season respectively. The Wote accession also recorded the highest Na content in seasonal average (2.27 mg/100g) with Siakago accession recording the lowest seasonal average of 1.10 mg/100g (Table 4.14). The accessions also varied significantly ($P<0.05$) in Iron (Fe) content. Nyakoe accession had the highest Fe content of 3.06 mg/100g while Maragua accession had the lowest content of 1.15 mg/100g in season 1 (Table 4.12). In the second season, the highest Fe content of 2.50 mg/100g was recorded in the Kianjokoma accession while the lowest was 0.31 mg/100g recorded in Embu accession (Table 4.13). In the seasonal averages, Kianjokoma and Maragua accessions maintained the highest and lowest Fe content of 2.61 mg/100g and 0.81 mg/100g, respectively (Table 4.14). Significant ($P<0.05$) variation among accessions in Vitamin C content was only observed in the second season experiment (Table 4.13). Kianjokoma accession had the highest Vitamin C content (2.87 mg/100g) while Kathwana accession had the lowest content (1.18 mg/100g).

Table 4.12: Nutrient Composition of Horned Melon Accessions for Season 1

Accessions	MC (%)	Mass Sugar (%)	Potassium (mg/100g)	Phosphorus (mg/100g)	Sodium (mg/100g)	Iron (mg/100g)	Vitamin C (mg/100g)
Kathwana	89.72	3.053^{cdef}	245.13^{a}	16.38^{gh}	1.46^{ab}	2.207^{bcd}	1.88
Meru	94.14	2.14^{g}	166.43^{cde}	19.69^{fg}	1.37^{ab}	1.357^{e}	1.95
Siakago	89.70	4.63^{a}	218.43^{ab}	42.80^{b}	1.13^{b}	2.703^{ab}	2.55
Maragua	90.14	2.96^{cdef}	166.47^{cde}	10.68^{h}	1.55^{ab}	1.150^{e}	1.73
Chuka	91.68	3.28^{cde}	210.07^{abc}	11.52^{h}	1.52^{ab}	1.723^{de}	1.50
Kehancha	90.69	3.68^{bc}	226.43^{ab}	29.04^{de}	1.86^{ab}	1.627^{de}	1.86
Narok	90.69	2.72^{cdef}	119.97^{ef}	11.00^{h}	1.62^{ab}	2.570^{abc}	1.51
Kianjokoma	92.75	3.33^{cde}	227.37^{ab}	35.64^{c}	2.03^{ab}	2.710^{ab}	1.81
Kangundo	92.39	2.54^{fg}	244.73^{a}	8.76^{h}	1.62^{ab}	2.463^{abc}	1.60
Kwale	90.17	3.56^{bcd}	215.23^{ab}	32.90^{cd}	1.97^{ab}	2.173^{bcd}	1.69
Rongo	89.73	2.54^{fg}	202.40^{abc}	12.55^{h}	2.28^{a}	1.523^{de}	1.32
Machakos	90.57	2.94^{cdef}	227.10^{ab}	8.81^{h}	1.76^{ab}	1.957^{bcde}	1.24
Migori	89.75	3.55^{bcd}	227.10^{ab}	48.1^{a}	1.93^{ab}	1.873^{cde}	6.84
Mitunguu	90.92	3.40^{cde}	189.27^{bcd}	9.67^{h}	2.03^{ab}	1.620^{de}	3.19
Wote	92.29	3.23^{cde}	207.20^{abc}	11.93^{h}	2.19^{ab}	1.307^{e}	2.06
Kiambere	92.10	3.02^{cdef}	116.43^{f}	11.48^{h}	1.52^{ab}	1.390^{e}	1.72
Embu	90.71	3.46^{cde}	146.57^{def}	24.44^{ef}	1.47^{ab}	1.573^{de}	1.62
Nyakoe	91.47	4.03^{b}	201.10^{abc}	9.76^{h}	1.37^{ab}	3.063^{a}	2.11
Oyugis	92.35	3.10^{cdef}	224.50^{ab}	13.14^{h}	1.31^{ab}	2.237^{bcd}	1.59
P value	0.813^{NS}	0.0001	0.0001	0.0001	0.0142	0.0001	0.405^{NS}
S.E	1.522	0.148	9.009	1.716	0.215	0.167	0.185

NB: Means followed by the same letter are not significantly different at p= 0.05

Table 4.13: Nutrient Composition of Horned Melon Accessions for Season 2

Accessions	MC (%)	Mass Sugar (%)	Potassium (mg/100g)	Phosphorus (mg/100g)	Sodium (mg/100g)	Iron (mg/100g)	Vitamin C (mg/100g)
Kathwana	93.46^{bcd}	4.15^{def}	237.73^{ab}	33.90^{b}	1.46^{abc}	0.630^{efg}	1.18^{f}
Meru	92.25^{ef}	4.06^{ef}	191.07^{abc}	41.25^{a}	1.34^{bc}	0.747^{defg}	1.95^{c}
Siakago	94.41^{abc}	3.53^{hi}	225.97^{abc}	12.76^{def}	1.08^{c}	1.160^{bcd}	1.53^{def}
Maragua	93.18^{cde}	3.47^{i}	193.00^{abc}	19.63^{cde}	1.43^{abc}	0.460^{g}	1.82^{cd}
Chuka	94.44^{abc}	4.18^{de}	220.70^{abc}	20.90^{cd}	1.41^{bc}	0.657^{efg}	1.73^{cde}
Kehancha	94.61^{ab}	5.09^{a}	224.97^{abc}	26.42^{bc}	1.82^{abc}	0.543^{fg}	1.86^{cd}
Narok	94.21^{abc}	3.55^{hi}	237.17^{ab}	12.80^{def}	1.73^{abc}	2.450^{a}	1.81^{cd}
Kianjokoma	93.36^{bcd}	4.40^{c}	230.70^{abc}	22.90^{cd}	2.18^{ab}	2.504^{a}	2.87^{a}
Kangundo	93.56^{abcd}	3.53^{hi}	254.30^{a}	9.51^{ef}	1.47^{abc}	2.463^{a}	2.02^{c}
Kwale	93.79^{abcd}	3.07^{j}	211.20^{abc}	26.90^{bc}	1.46^{abc}	0.390^{g}	1.85^{cd}
Rongo	94.41^{abc}	4.27^{cd}	214.80^{abc}	16.30^{def}	1.73^{abc}	0.787^{defg}	1.21^{f}
Machakos	93.80^{abcd}	3.64^{h}	246.23^{ab}	8.71^{f}	1.37^{bc}	0.391^{bc}	2.61^{b}
Migori	93.03^{abcd}	4.36^{c}	232.07^{abc}	32.88^{b}	1.74^{abc}	1.453^{b}	1.23^{f}
Mitunguu	93.46^{bcd}	4.35^{c}	205.03^{abc}	10.27^{ef}	2.00^{abc}	1.077^{bcde}	1.80^{cd}
Wote	91.82^{f}	3.79^{g}	220.07^{abc}	15.00^{def}	2.36^{a}	1.00^{cdef}	1.40^{f}
Kiambere	94.84^{a}	3.53^{hi}	167.70^{c}	14.07^{def}	1.64^{abc}	0.354^{g}	2.06^{c}
Embu	94.06^{abcd}	4.98^{b}	183.7^{bc}	15.12^{def}	1.55^{abc}	0.314^{g}	1.43^{ef}
Nyakoe	91.52^{f}	4.04^{f}	206.77^{abc}	10.47^{ef}	1.57^{abc}	0.963^{cdef}	1.75^{cde}
Oyugis	92.86^{de}	3.66^{hi}	244.60^{ab}	17.53^{def}	1.48^{abc}	0.450^{g}	1.96^{c}
P value	0.0001	0.0001	0.0010	0.0001	0.0034	0.0001	0.0001
S.E	0.276	0.036	12.646	2.183	0.183	0.106	0.083

NB: Means followed by the same letter are not significantly different at p= 0.05; MC = Moisture Content

Table 4.14: Nutrient composition of horned melon accessions for Combined Seasons

Accessions	MC (%)	Mass Sugar (%)	Potassium (mg/100g)	Phosphorus (mg/100g)	Sodium (mg/100g)	Iron (mg/100g)	Vitamin C (mg/100g)
Kathwana	91.50	3.60^{efg}	241.43^{ab}	25.14^{b}	1.38^{cd}	1.42^{cd}	1.53
Meru	93.19	3.10^{ij}	178.75^{ef}	30.48^{b}	1.36^{cd}	1.05^{defg}	1.95
Siakago	91.99	4.08^{bc}	222.20^{abcd}	27.78^{b}	1.10^{d}	1.93^{b}	2.04
Maragua	91.66	3.22^{hij}	179.73^{ef}	15.16^{cde}	1.49^{bcd}	0.80^{g}	1.78
Chuka	93.06	3.73^{def}	215.38^{abcd}	16.21^{cd}	1.47^{bcd}	1.19^{defg}	1.61
Kehancha	92.65	4.39^{a}	225.70^{abcd}	27.73^{b}	1.84^{abc}	1.08^{defg}	1.86
Narok	92.45	3.13^{ij}	178.57^{ef}	11.90^{def}	1.68^{abcd}	2.51^{a}	1.66
Kianjokoma	93.06	3.86^{cde}	229.03^{abcd}	29.27^{b}	2.11^{ab}	2.61^{a}	2.34
Kangundo	92.98	3.04^{j}	249.52^{a}	9.14^{ef}	1.55^{bcd}	2.46^{a}	1.81
Kwale	91.98	3.32^{ghij}	213.22^{abcd}	29.90^{b}	1.71^{abcd}	1.28^{cdef}	1.77
Rongo	92.07	3.41^{ghi}	208.60^{bcde}	14.43^{cdef}	2.01^{abc}	1.16^{defg}	1.27
Machakos	92.19	3.29^{hij}	236.97^{abc}	8.76^{f}	1.57^{bcd}	1.67^{bc}	1.92
Migori	91.89	3.96^{bcd}	229.58^{abcd}	40.49^{a}	1.83^{abc}	1.66^{bc}	4.03
Mitunguu	92.20	3.87^{cde}	197.15^{de}	9.97^{def}	2.02^{abc}	1.38^{cde}	2.49
Wote	92.06	3.51^{fgh}	213.63^{abcd}	13.46^{def}	2.27^{a}	1.15^{defg}	1.73
Kiambere	93.47	3.28^{hij}	142.07^{g}	12.78^{def}	1.58^{bcd}	0.87^{fg}	1.89
Embu	92.38	4.22^{ab}	165.17^{f}	19.78^{c}	1.51^{bcd}	0.94^{efg}	1.53
Nyakoe	91.49	4.03^{bc}	203.93^{cde}	10.15^{def}	1.43^{bcd}	2.01^{b}	1.93
Oyugis	92.61	3.35^{ghij}	234.55^{abc}	15.34^{cde}	1.40^{cd}	1.34^{cde}	1.77
P value	0.9467^{NS}	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.5310^{NS}
S.E	0.773	0.076	7.763	1.388	0.141	0.099	0.594

NB: Means followed by the same letter are not significantly different at p= 0.05; MC = Moisture Content

4.2.1 Correlation between the Nutrients in Horned Melon

There was insignificant (P>0.05) correlation between majority of the tested nutrients. However, there were significant correlations (P<0.05) between Potassium and Iron content (0.453) and between Vitamin C and Iron (0.386) as shown in table 4.15. There were no significant correlations between the nutritional composition and agro-morphological traits of the horned melon accessions that were studied (data not presented).

Table 4.15: Correlation between Nutrient Elements tested in the study

Variables	%MC					
Sugar	0.121	**Sugar**				
K	-0.032	-0.103	**K**			
Na	-0.084	0.249	-0.133	**Na**		
Fe	-0.001	-0.106	**0.453**	0.210	**Fe**	
Vitamin C	-0.003	-0.180	0.078	0.112	**0.386**	**Vitamin C**
P	-0.074	0.220	-0.057	-0.055	-0.221	-0.168

NB: Values in bold are different from 0 with a significance level alpha=0.05; MC = Moisture Content

4.2.2 Cluster Analysis using Nutritional Composition

Agglomerative hierarchical clustering conducted using the nutritional variables separated the accessions into 5 supported clusters of the dendrogram. The diversity between classes was estimated at 90.51% thus the diversity within classes was only 9.49%. Kiambere accession separated in its own supported singleton cluster (cluster 5) while the rest of the clusters had either 4 or 5 members. The accessions from Rongo, Wote, Chuka, Mitunguu and Nyakoe grouped together in cluster 1 while Migori, Kwale, Kianjokoma, Kehancha and Siakago accessions also grouped together in cluster 2. The accessions from Kathwana, Kangundo, Machakos and Oyugis grouped together in cluster 4 those from Embu, Meru, Maragua and Narok grouped together in cluster 5 (Figure 4.5). There seemed to be no relationship between the nutritional composition of the accessions and proximity of their origin.

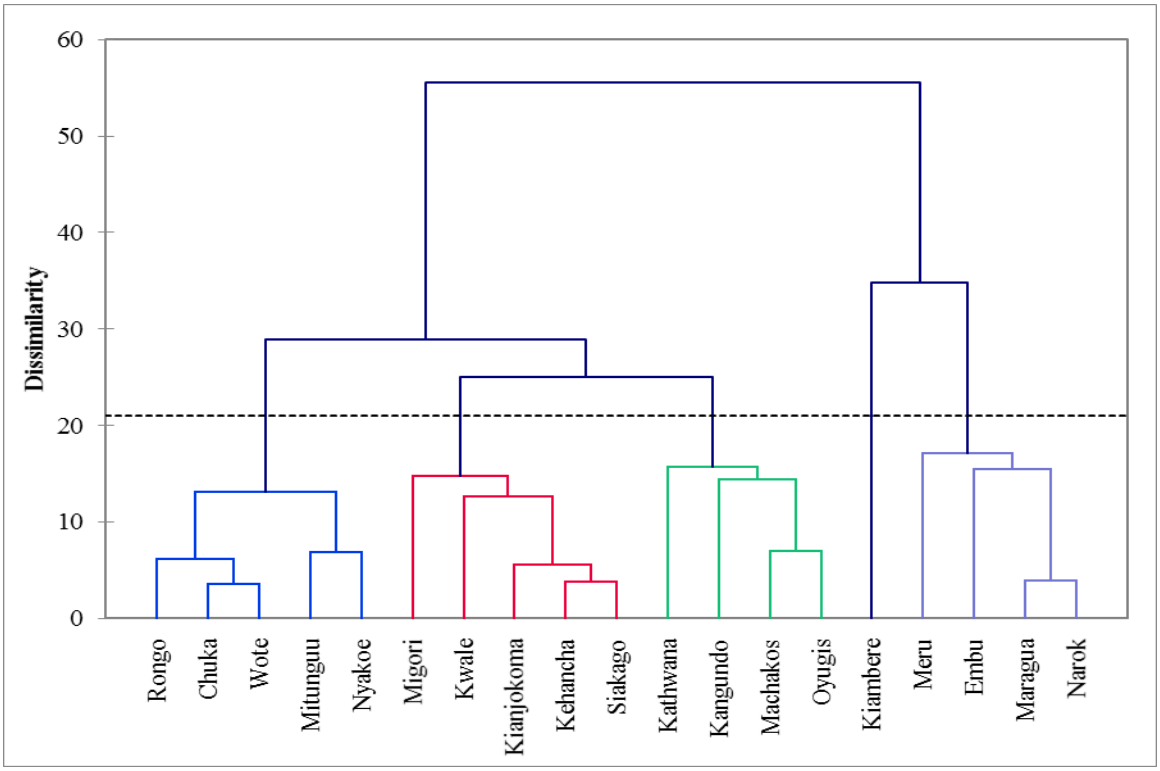


Figure 4.5: Cluster Dendrogram Illustrating Nutritional Diversity between Horned Melon Accessions

CHAPTER FIVE

DISCUSSION

5.1 Agro-morphological Diversity

Significant diversity was observed between the horned melon accessions based on agro-morphological variation except fruit shape, seed shape and predominant rind colour. Similar observation was made by Bisognin (2002) and Gichimu *et al.* (2009a) who reported that cucurbits are similar in above ground development but have high genetic diversity in fruit characteristics such as fruit shape, flesh colour, seed shape and seed colour. Most of the accessions (74%) had elliptically shaped fruits while the rest (26%) had cylindrically shaped fruits. Most of the accessions (63.16%) had elliptically shaped seeds while the rest (36.84%) had pinonette shaped seeds. This observation concurred with earlier report by Bester & Condy (2013) that the fruits of *Cucumis metuliferus* were ellipsoid-cylindrically shaped. The rind colour varied from light green to dark green with majority of the accessions being dark green. However, the fruit colour in all accessions changed to bright orange at ripening. Similar observation was made by Dembitsky *et al*. (2011) and Mey (2014).

Quantitative characters that were evaluated include main vine length, number of branches on the main vine, fruit number, fruit weight, rind thickness and seed number. The former four are considered to be yield components while the latter two are quality components (Gichimu *et al.,* 2009b). Among the yield components, only fruit number recorded significant differences among accessions; ranging from an average of 17 fruits produced by the Rongo accession to 7 fruits produced by Kangundo accession. Unfortunately, the prolific nature of the Rongo accession may have compromised the fruit weight which averaged 204 g, a far cry from 259 g recorded in Oyugis and Meru accessions. However, this could be possibly improved by enhancing the soil fertility since high yielding accessions are expected to have a relatively higher demand of essential nutrients. Apparently, *C. metuliferus* is highly variable in terms of fruit yield as different studies have reported divergent data on fruit number and weight. April *et al.* (2018) reported that each vine is capable of producing up to 100 fruits. In a study evaluating 26 *C. metuliferus* plant introductions in Missouri, United States, Marsh (1993) obtained fruit numbers

ranging from 14 to 101 fruits per plant but with relatively lower fruit weights ranging from 12 to 31 grams.

For successful yield selection, all the yield components should be considered. Although there were no significant variations among accessions in vine length and branch number, these variables are expected to have a significant influence on yield as reported by April *et al*. (2018). Similar observation was also made by Deepa *et al.* (2018) in cucumber who also reported that the yields were strongly correlated to branch number and vine length ($p=0.677$). In the contrary and against expectations, this study observed no significant correlation between the yield components. This observation was supported by the fact that some accessions managed to produce many fruits despite not being well endowed with long vines and many branches. Similarly, some accessions with long vines and many branches produced relatively fewer fruits. This was an indication that there is great breeding potential to improve the yields of horned melon through selective hybridization of accessions possessing desirable yield components. For example, the potential of the Rongo accession can be further expanded by increasing the vine length and branch number through hybridization with the Wote accession which was found to combine long vine length with high branch number and fruit number.

Significant differences among accessions were also recorded in seed size and rind thickness. This evaluation was important because both the seeds and the rind of horned melon are edible. The seed size ranged from 3.17 mm recorded in Kiambere accession to 4.10 mm recorded in Maragua accession. This observation was divergent from what was reported by Wilkins-Ellert (2004) that the seeds of *C. metuliferus* are 5 – 8 mm long. All accessions had more than 100 seeds per fruit. Rind thickness also varied from 5.37 mm recorded in the Machakos accession to 3.01 mm recorded in the Nyakoe accession. There was no available data in literature comparing the rind thickness among different accessions of horned melon. However, for the watermelon, the rind thickness ranged from 7-24 mm (FAO, 2011). There were slight significant seasonal variations between accessions for all the quantitative variables indicating that the accessions were stable and may not be significantly affected by genotype by environment interactions (Appendix 9).

This is a positive agronomic trait that would ensure constant productivity of the horned melon across variable weather conditions. However watermelon had a rind thickness of more than 10 mm (Abdullah *et al.*, 2017)

Although there were no significant variations among accessions in fruit weight and main vine length, the principal component analysis indicated that the two had the highest contribution to the total variation observed between the nineteen accessions studied. This was an indication that there was a high potential of agronomic selection among the accessions based on these variables. The average length of the main vine ranged from 236.75 cm recorded in the Narok accession to 277.08 cm recorded in Wote accession. This big gap between the shortest and the longest vine is an indication of the improvement potential among the accessions studied. However, the vine length obtained in this study fell short of the 5 meters length reported by April *et al.* (2018). Similarly, high improvement potential was observed in fruit weight whose variation among accessions varied from 195.0 grams produced by Machakos accession to 259.33 grams produced by Meru and Oyugis accessions. This was slightly high than the average of 200 grams reported by Wilkins-Ellert (2004) in Israel. However, unlike vine length whose potential is a combined effect of the genetics and agronomic nourishment, fruit weight may be affected by fruit number unless the plant is adequately and timely supplied with all essential growth resources.

Unlike the growth variables, other agronomic variables namely, percent germination, days to seed emergence, days to male and female flowering and days to maturity, recorded highly significant variations between accessions. This was expected as all these variables are liable to be affected by the weather especially the temperature and the accessions were all collected from different geographical locations where they were used to different weather patterns. Variation in flowering time on *C. metuliferus* was also reported by Weng (2010). Most of the accessions recorded high viability of between 80 and 100% except five accessions whose germination percentage was lower than 80%. These were accessions from Kehancha, Rongo, Narok and Oyugis. This observation was consistent over the two seasons indicating that its cause could be morphology linked and acquired

from the original habitat. Aliero and Gumi (2012) also observed high germination percentage averaging 96.66% with untreated seeds of horned melon. Significant positive correlation that was observed between days to male and female flowering and days to maturity was an indication that these variables are morphologically linked thus selection for one would automatically improve the others. Principal component analysis also showed that the three variables contributed significantly to the total variation observed between the accessions and therefore they can be easy targets for selective improvement of the accessions.

A cluster dendrogram developed using the qualitative and quantitative traits as well as the agronomic variables indicated that there was significant agro-morphological variation between the accessions studied. The accessions separated into five (5) clusters with a between classes diversity of 63.82% in the first season and 68.84% in the second season thus the diversity within classes was 36.18% in the first season and 31.16% in the second season. This was a considerable high level of genetic diversity for accessions of the same species and further underscores the enormous selection potential that exists within horned melon accessions and the observed clustering was influenced by environmental factors and not genetics. There are scanty reports on the genetic characterization of *C. metuliferus* accessions in Kenya. A related study conducted by Gichimu *et al*. (2009a) on watermelon accessions obtained relatively lower genetic diversity of 42-54% between classes and 8-27% within classes. Other previous studies conducted by Henan *et al.* (2013) on muskmelon in Tunisia and Solmaz *et al*. (2010) on melon genotypes collected from Eastern and Central Anatolia region of Turkey also reported high morphological variation between cucurbits. In another genetic diversity study conducted by Weng (2010) among *C. metuliferus* accessions using cucumber microsatellites, unexpectedly low genetic diversity was observed between 36 accessions. The 42 microsatellite markers only managed to separate the accessions into six supported groups detecting on average 3.3 alleles across the 36 *C. metuliferus* accessions and 12 of them were monomorphic.

The effect of the region of origin of the accessions was evident as most accessions clustered according to the proximity of their places of origin (where they were collected).

For example, the Wote, Machakos and Chuka accessions all of which were from the Eastern Kenya region clustered together as it was the case with Kathwana, Kangundo, Mitunguu, Kiambere and Kianjokoma accessions which were also from Eastern Kenya region. The similarity of accessions from the regions of close proximity was further evident in the two dimensional presentation which plotted the accessions at proximal distances based on their similarity and cross pollination. Similar observation was reported by Weng (2010) when studying the genetic diversity of *Cucumis metuliferus* populations using cucumber microsatellites where he noted that accessions that were collected from nearby locations were clustered in the same group. However, some accessions that were collected from distinctively diverse geographical regions clustered together which was an indication of high agronomic potential of horned melon over a wide range of environmental conditions. This observation was further supported by the fact that all the nineteen accessions with diverse geographical origin managed to produce appreciably in a common location. Therefore, there is wide agronomic range of horned melon in Kenya. This supports the previous report by Wilkins-Ellert (2004) that horned melon occurs at altitudes from near sea level to 1800 m and tolerate a wide range of soil types throughout their natural distribution area.

5.2 Nutrient Composition of Horned Melon Accessions

Horned melon has been recently attracting attention due to their high nutrient quality (Usman *et al.*, 2015). This study established that there were significant differences among horned melon accessions for the proximate and nutrient traits. The accessions studied were found to have sufficiently higher moisture content ranging between 90 and 95%. This observation concurred with an earlier report by Andrés et al. (2016) that horned melon fruit contains about 90% moisture. The high moisture content compares with that of other cucurbits including cucumber, netted melons, watermelon, summer squash and winter squash that are reported to have a moisture content of 96%, 90.15%, 92.6%, 94% and 89% respectively (Cantwell & Suslow 2013; FAO, 2011 and USDA, 2011). The moisture content indicates the lifespan of the fruit (Fellows, 2000) and high moisture is typical for fresh fruits at maturity (Abiodun & Adeleke, 2010). The high moisture content in the

cucurbits promotes them a good sources of water for animals and human in the arid and semi-arid areas (April *et al.*, 2018).

Sugar content varied significantly among accessions and among seasons. In the first season, the sugar content ranged between 2.14 and 4.63 g/100g but increased in the second season to a range of 3.07 to 5.09 g/100g. These levels of sugar content were relatively low compared to what is reported in other melons. Suslow et al. (2013) reported sugar content of 7.86g/100g in netted melon. The general increase in sugar content in season 2 as compared to season 1 was attributed to the dry weather experienced in season two. Abiodun & Adeleke (2010) reported that increase in moisture content in the fruit reduces the sugar content due to dilution and subsequent water loss. Kehancha accession consistently recorded high sugar content with minimal variations over the seasons. Embu and Migori accessions also consistently recorded high levels of sugar content. This was an indication that there is a potential for selection for high sugar content within the Kenyan horned melon accessions. Sugar is considered to be one of the basic taste qualities for most fruits and vegetables. Sweet taste enhances preference thus enhances consumption and the vice versa (Cadet, 2014).

The studied accessions recorded high levels of Potassium (K) ranging from 116.43 mg/100g to 245.13 mg/100g in season one and from 167.70 mg/100g to 254.30 mg/100g in season two. This observation corroborates earlier reports that horned melon is very rich in potassium content just like other cucurbits. Rudrappa (2019) reported that fresh fruits of horned melon contain 123 mg/100g of K which is relatively lower than what was observed in most accessions in this study. Previous studies on other cucurbits reported that edible fruits of summer squash, winter squash, watermelon and cucumber had high potassium content of 195mg/100g, 350mg/100g, 100mg/100g and 149mg/100g respectively (Masabni *et al.,* 2011; Cantwell & Suslow 2013; Suslow *et al*., 2013). Potassium has much influence on the fruit quality for instance the fruit color, appearance, size, acidity and improved drought resistance (Kumar et al., 2006). It also has many functions like enhancing plant metabolic processes, increased root growth, reduced water loss and improved resistance to pests and diseases (Kumar et al., 2006). The benefits of high K

intake in human bodies include prevention of stroke, coronary heart disease and hypertension (Weaver, 2013).

Phosphorous (P) content was also found to vary significantly among accessions ranging from 8.76 mg/100g to 48.10 mg/100g in the first season and from 8.70 mg/100g to 41.27 mg/100g in the second season. The P content reported by Rudrappa (2019) of 37 mg/100g falls within this range. Comparable levels of 35mg/100g and 32mg/100g of P were reported in summer and winter squash by Bello et al. (2014). In the same study they reported relatively lower levels of 17mg/100g and 10mg/100g of P in cucumber and watermelon. Phosphorus is needed in the body for maintaining the cell structure, regulation of cellular signalling, maintaining acid-base homeostasis and bone mineralization (Mcclure *et al*., 2014). Recommended P intake for adults is 600-700mg/day hence consumption of a few horned melon fruits per day is enough to achieve the daily P requirement (Karp, 2013).

The sodium (Na) content observed in the study ranged from 1.13 to 2.28 mg/100g in season 1 and 1.08 to 2.36 mg/100g in season two. Rudrappa (2019) reported that fresh fruits of horned melon contain 2 mg/100g of Na. Previous studies conducted on other cucurbits reported that plants like cucumber, watermelon, summer squash and winter squash had Na content of 1.1mg/g, 1mg/100g, 2mg/100g and 4mg/100g respectively (USDA, 2011; Bello e*t al.*, 2014). Sodium is very essential in maintaining the water balance within the cells, muscle contraction and nervous system functions. Low sodium and high levels of K in human diet have been reported to be beneficial in the prevention of high blood pressure (Nerdy, 2018). The nutrient Na is only required in small quantity and when in excess, it is excreted by the kidney (Noubiap *et al*, 2015). This makes horned melon a suitable fruit in regulating the blood pressure which is a major cause of death in the world.

The studied accessions were also found to vary significantly in the Iron (Fe) content in their fruits. The Fe content ranged from 1.15 mg/100g to 3.06 mg/100g in season one and from 0.314 mg/100g to 2.50 mg/100g in season two. These levels were higher than those

reported by Rudrappa (2019) that horned melon contain 1.13 mg/100g of Fe. Studies conducted on other cucurbits showed that cucumber, netted melon, watermelon, summer squash and winter squash to have 0.3mg/100g, 0.21mg/100g, 0.5mg/100g, 0.5mg/100g and 0.6mg/100g of iron content respectively (Nair & Iyengar, 2009; Brown & Hodgkin, 2015). Horned melon therefore contains more than double the levels of Fe contained in other cucurbits thus making it an important source of this micronutrient. Iron plays a role in oxidation metabolism, transport and cellular proliferation (Nair & Iyengar, 2009). Lack of Fe in the body causes anaemia which is a disease that affects all ages in a population but especially breast feeding and the pregnant mothers (Lonnerda *et al*., 2006). The range required for adults is 8.7mg/day in males and 14.8mg/day in females hence consumption of a few horned melon fruits per day is enough to achieve this daily requirement. There was significant positive correlation between Fe and K content. This concurred with the finding of Asri & Sonmez (2012) who reported a positive correlation between Fe and K content in tomatoes.

The levels of Vitamin C observed among horned melon accessions analysed in this study ranged from 1.24 to 6.84 mg/100g in season one and from 1.18 to 2.87 mg/100g in season two. On average, the observed levels were relatively low compared to the levels reported by Rudrappa (2019) of 5.3 mg/100g. The observed Vitamin C levels were also relatively low compared to the levels reported on other cucurbits. Studies conducted by Consoli & Camargo (2015), Bello *et al.* (2014) and USDA (2011) on Cucurbits reported that cucumber, netted melon, watermelon, summer squash, winter squash and ash gourd had vitamin C content of 4.7 mg/100g, 38.7 mg/100g, 7.0 mg/100g, 14.7 mg/100g, 12.3 mg/100g and 13 mg/100g, respectively. Lim (2012) reported that horned melon contains twice the amount of Vitamin C found in cucumber which also varied with the levels observed in this study. The low levels of vitamin C observed in this study was attributed to external rather than genetic factors. According to Lee and Kader (2000), vitamin C content can be influenced by pre-harvest and post-harvest factors including prevailing climatic conditions and cultural practices. There was significant correlation between Iron and Vitamin C content indicating that Iron content increased as Vitamin C content increased.

Generally, the nutrients levels observed in season 2 were higher that the levels recorded in season 1. This was attributed to the prevailing weather conditions where the first season received more rainfall than the second season during which the rainfall levels dropped drastically (appendix 8). Babita *et al.* (2010) reported that water stress promotes accumulation of total soluble solids (TSS) in crops as an adaptation mechanism including sugar, glycerol and proline in water melon (Huang *et al.*, 2009b). However, in crops like onions, water stress does not affect the TSS amount (Kumar *et al.,* 2007). Martinelli *et al*., 2010 also reported that water drought affects mineral component by reducing K levels while Ca, Fe, Na and Zn are increased. However, Esmaeilian *et al.* (2012) reported that water stress favours K accumulation.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 Summary of findings

Qualitative variations among accessions were only observed in fruit shape, predominant rind colour and seed shape. The rest of the qualitative traits, namely growth habit, leaf blade, leaf shape, flower biology, corolla colour, secondary skin colour, presence of grooves on the fruit, flesh colour and seed colour, were not variable among accessions.

There were significant differences between accessions for seed size, rind thickness and fruit number. The means for all the other quantitative variables were not significantly different among accessions. However, there were highly significant differences in all agronomic traits, namely percent germination, days to emergence, days to male flowering, days to female flowering and days to maturity. Significant correlations between agronomic traits were only observed in the reproductive traits i.e. between days to male and female flowering and days to maturity. Other quantitative traits appeared to be independent of each other and therefore, none of them can be used to select for the other during agronomic improvement of this crop. There were significant seasonal variations between accessions for all the quantitative variables indicating that the accessions were genetically stable and may not be significantly affected by genotype by environment interactions.

Cluster analysis using agro-morphological traits depicted high level of diversity between accessions of 63.82% and 68.84% in the first and second season, respectively. There appeared to be close proximity between Maragua, Meru and Siakago accessions which clustered together in both seasons. Rongo, Narok and Migori accessions also grouped together in both seasons. The rest of the accessions grouped together in the biggest cluster of 10 members in season 1 which separated further in season 2 to form two supported clusters with Wote, Chuka and Machakos in one cluster. However, some accessions that were collected from distinctively diverse geographical regions clustered together which was an indication of high agronomic potential of horned melon over a wide range of environmental conditions. This observation was further supported by the fact that all the

nineteen accessions with diverse geographical origin managed to produce appreciably in a common location. Therefore, there is wide agronomic range of horned melon in Kenya.

Principal component analysis showed that the variables contributed differently to the observed variation with fruit weight and main vine length contributing the highest to F1 and F2 respectively in both seasons. On the other hand, days to male and female flowering and days to maturity had the highest contribution to F3. The rest of the variables contributed minimally to the three principal factors. These factors that showed the highest contribution to the observed diversity should be most targeted for selection during agronomic improvement of this crop.

There was high diversity between horned melon accessions in terms of their sugar content and nutritional composition. This diversity can be exploited by plant breeders for improvement of the eating and nutritional quality of the crop. The levels of nutritional content of horned melon was found to be either comparable or higher than the content in other cucurbits. Considering the prolific nature of horned melon, the crop can play a major role in nutritional security of the Kenyan community. Similarly, there were insignificant correlations between majority of the tested nutrients. Unlike in the agro-morphological variation, there seemed to be no relationship between the nutritional composition of the accessions and proximity of their origin.

6.2 Conclusion

This study established that there exists significantly high agro-morphological and nutritional variation within horned melon which can be exploited by plant breeders for genetic improvement of this high value crop whose potential is yet to be fully utilized. The study further established that there is great breeding potential to improve the yields of horned melon through selective hybridization of accessions possessing desirable yield components. In addition, the study findings indicated that horned melon has a high agronomic potential over a wide range of environmental conditions as accessions from diverse geographical regions recorded appreciable yields in a common location. The crop was also found to have high content of important nutritional components and can therefore

play a significant role in ensuring food and nutritional security among households. Therefore, plant breeders should embark on improving the agronomic and quality attributes of this crop through targeted selection and hybridization. The best performing cultivars should then be promoted among farmers in all agro-ecological zones in Kenya. In addition, some accessions that possess other desirable attributes such as relatively high sugar levels and nutrient content can be harnessed by plant breeders for further improvement eating and nutritional quality of this valuable crop.

6.3 Recommendations

1) This study established existence of breeding potential to improve the yields of horned melon through selective hybridization of accessions possessing desirable yield components.
2) All the nineteen accessions with diverse geographical origin managed to produce appreciably in a common location indicating that there is wide agronomic range of horned melon in Kenya. This study therefore recommends promotion of horned melon production in all agro-ecological zones in Kenya where basic agricultural resources are not limiting.
3) Kehancha accession consistently recorded high sugar content with minimal variations over the seasons. Embu and Migori accessions also consistently recorded high levels of sugar content. The three accessions are therefore recommended to plant breeders seeking to improve taste of horned melon which is considered by some consumers to be bland and less appealing.

6.4 Opportunities for Further Research

The use of molecular markers would complement the study by identifying greater polymorphism that exist amongst the accessions. This would be a great step establishing the more advanced genetic diversity. Further evaluation should be done using more accessions and looking at more traits than the ones used in this study as this would widen the scope of diversity for further selection. Further study is also recommended to analyse the anti-nutritional components of horned melon.

REFERENCES

Abdullah, E., Idris, A., & Saparon, A. (2017). Papr reduction using scs-slm technique in stfbc mimo-ofdm. *ARPN Journal of Engineering and Applied Sciences*, *12*(10), 3218–3221. https://doi.org/10.1111/ijlh.12426

Abiodun, O. A. & Adeleke, R. O. (2010). Comparative studies on nutritional composition of four melon seeds varieties. *Pakistan Journal of Nutrition*, *9*(9), 905–908. https://doi.org/10.3923/pjn.2010.905.908

Aliero, A. A., & Gumi A.M. (2012). Studies on the germination, chemical composition and antimicrobial properties of *Cucumis metuliferus* Studies on the germination, chemical composition and antimicrobial properties of *Cucumis metuliferus*. *Annals of Biological Research,* 3 (8):4059-4064.

Andrés, C., María B., & Carmina G. (2016). Germination of Wild *Cucumis Species and* Interspecific Hybrids. *Proceedings of Cucurbitacea 2016 pp 227–230.* Accessed on 18th May 2018.

Anon., (2014). *The horned melon or Kiwano: Its nutrition and gastronomical Uses.* Online Publication: http://food-nutrition.knoji.com/the-horned- melon-or-kiwano-its-nutrition-and-gastronomical-uses. Accessed on 6th April 2018.

April, M., Usman, J. G., Sodipo, O. A., Kwaghe, A. V., Wampana, B., & John, N. (2018). Effects of crude methanol extract of the fruit of *Cucumis metuliferus* (Cucurbitaceae) on some haematological parameters in Cockerels. *The Journal of Phytopharmacology* 2018; 7(2): 106-1107(2).

Asri, F.O., & Sonmez, S. (2012). Effects of different potassium and iron levels on seasonal changes of nutrient concentrations of tomato plant grown in soilless culture. *African Journal of Agricultural Research*, 7(1), 28-33. https://doi.org/10.5897/AJAR11.1119

Babita, M., Maheswari, M., Rao, L.M., Shanker, A.K., Rao, D.G. (2010). Osmotic adjustment, drought tolerance and yield in castor (*Ricinus communis* L.) hybrids. *Environ Exper Bot* 69: 243–249

Bello, M., Abdul-hammed, M., & Yekeen, T. A. (2014). Characterization of gourd fruits (Cucurbitaceae) for dietary values and anti- nutrient constituents. *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* 416-424

Bester, S.P., & Condy, G. (2013). *Cucumis metuliferus* E.Mey. Ex Naudin. *Flowering Plants of Africa* 63: 56-64.

Berlingeri, C., & Crespo, M.B. (2012). Inventory of related wild species of priority crops in Venezuela. *Genetic Resources and Crop Evolution,* 59(5): 655-681.

Bisognin D.A., (2002). Origin and Evolution of Cultivated Cucurbits. *Ciência Rural, Santa Maria*. 32 (5): 715-723. Accessed on 10th June 2018.

Bob, K., (2018). Farmbizafrica. Meru County leading in cultivation of thorny melon fruit in 2018. Online Publication: http://farmbizafrica.com/market/2216.b Retrieved on 30th April 2018.

Brown, A. D., & Hodgkin, T., (2015). Indicators of Genetic Diversity , *Genetic Erosion , and Genetic Vulnerability for Plant Genetic Resources, 25–54*. https://doi.org/10.1007/978-3-319-25637-5

Cadet, F,. (2014). Quantitative determination of sugar in fruits by different methods.*Indian Journal of Chemistry*. Accessed on 30th June 2019.

Cantwell, M. (2011). Storage of Kiwano (Horned melon) fruits. Department of Plant Sciences, University of California, Davis CA 20 pg 3–7. Online Publication: http://ucanr.edu/datastoreFiles/234-2128.pdf Retrieved on 30th April 2018.

Cantwell, M.,& Suslow, T., (2013) Pumpkin and Winter Squash: Recommendations for Maintaining Postharvest Quality. Available at: http://postharvest. ucdavis.edu/pfvegetable/PumpkinWinterSquash (accessed 18 November 2013)

Consoli, L., & Camargo, G. A., (2015). Determination of Mineral Composition of Organic and Conventional Beverages By Dispersive Energy X-Ray Fluorescence Spectrometry. *Revista Brasileira de Engenharia de Biossistemas*, *6*(3), 89. https://doi.org/10.18011/bioeng2012v6n3p89-101

Deepa, S.K., Hadimani H.P., Hanchinamani C.N., Shet R., Koulgi S. & Ashok (2018). Studies on Character Association in Cucumber (*Cucumis sativus* L.). *International Journal of Current Microbiology and Applied Sciences* 7(11): 1977-1982. doi: https://doi.org/10.20546/ijcmas.2018.711.224.

Dembitsky, V. M., Poovarodom, S., Leontowicz, H., Leontowicz, M., Vearasilp, S., Trakhtenberg, S., & Gorinstein, S. (2011). The multiple nutrition properties of some exotic fruits: Biological activity and active metabolites. *Food Research International*, *44*(7), 1671–1701. https://doi.org/10.1016/j.foodres.2011.03.003.

Deguine, J.P., Atiama-Nurbel, T., Aubertot, J.N., Augusseau, X., Atiama, M., Jacquot, M., & Reynaud, B. (2015). Agroecological management of cucurbit-infesting fruit fly: a review. *Agronomy for Sustainable Development*, *35*(3), 937–965. https://doi.org/10.1007/s13593-015-0290-5.

Engels, J.M., Diulgheroff S., & Alvarez J. S., (2014). Management of Crop Diversity: Key Practices for DRR Implementers. A Field Guide for Disaster Risk Reduction in Southern Africa. *FAO*: ISBN: 978-92-5-108330-7 (print); E-ISBN 978-92-5-108331-4 (PDF).

Esmaeilian, Y., Sirousmehr, A. R., Asghripour, M.R., & Amiri, E., (2012) Comparison of sole and combined nutrient application on yield and biochemical composition of sunflower under water stress. *Int J Appl Sci Tech* 2: 131–137.

FAO (2011). *The State of the World's Land and Water Resources for food and agriculture (SOLAW). Managing systems at risk*. Food and Agriculture Organization of the United Nations, Rome and London, Earth scan.

Fellows, P.J. (2000), "Food Processing Technology: Principles and Practice", *Woodhead Publishing in Food Science, Technology and Nutrition. Hook.*

Foster, N. (2003). What is *Cucumis?* Available online: http://www.wisegeek.com/what-is-*cucumis*.htm. Accessed on 20th May, 2018.

Gachimbi, L. N. (2002). Technical Report of Soil Survey and Sampling Results : Embu – Mbeere Districts, Kenya by Technical Report of Soil Survey and Sampling Results : Embu Mbeere Districts, *Kenya Land Use Change Impacts and Dynamics (LUCID) Project Working Paper #. Nairobi, Kenya: International Livestock Research Institute.* Accessed in June 2019.

Gichimu, B.M., Owuor, B.O., Mwai, G. N., & Dida, M. M. (2009a). Morphological characterization of some wild and cultivated watermelon (*Citrullus sp*.) accessions in Kenya, *ARPN Journal of Agricultural and Biological Science 4(2), 10–18.*

Gichimu, B.M., Owuor, B.O.& Dida, M. M. (2009b). Comparing the yield components of three most popular commercial watermelon cultivars in Kenya with one newly introduced cultivar and one landrace. *Journal of Plant Breeding and Crop Science* 1(4): 65-71.

Gisbert, C., Prohens, J., & Nuez, F, (2011). Treatments for improving seed germination in cucurbits and related species. In: Pascual J.A., Perez A.F. (Eds) Proceedings of the Fifth international symposium on seed, transplant and stand establishment of horticultural crops. *Acta Hort* 898: 45–51.

GoK (2013a). County Integrated Development Plan Meru County. Government of Kenya, Nairobi, Kenya.

GoK (2013b). County Integrated Development Plan Kwale County. Government of Kenya, Nairobi, Kenya.

GoK (2013b). County Integrated Development Plan Homa-Bay County. Government of Kenya, Nairobi, Kenya.

Gotep, J., (2011). Glycosides fraction extracted from fruit pulp of *Cucumis metuliferus* has anti hyperglycemic effect in rats with alloxan induced diabetes. *J. Nat. Pharm.* 2:48-51.

Govindaraj, M., Vetriventhan, M., & Srinivasan, M. (2015). Importance of Genetic Diversity Assessment in Crop Plants and Its Recent Advances . An Overview of Its Analytical Perspectives. *Genetics research international, 2015*.

Guan, W.X. Zhao, D.W., Dickson, M.L., & Mendes, J.T. (2014). Root-knot nematode resistance, yield, and fruit quality of specialty melons grafted onto *Cucumis metuliferus. HortScience.* Vol. 49, No. 8. p. 1046-1051.

Hayashi, K., Hashimoto, N., Daigen, M., & Ashikawa, I. (2004). Development of PCR-based SNP markers for rice blast resistance genes at the *Piz* locus. *Theor. Appl. Genet.* 2004, *108*, 1212–1220.

Henan, I., Tlili. I., Ilahy. R., Rhim K. & Jebari. H., (2013). Evaluation of qualitative parameters and physicochemical properties of local varieties of muskmelon (*Cucumis melo* L.) grown in Tunisia. *Global Science Books,* 7: 17-21.

Horticultural Crops Development Authority (HCDA) (2014). Horticultural Crops Development Authority. Horticulture Validated Report 2014. Nairobi, Kenya.

Horticultural Crops Development Authority (HCDA) (2016). Horticulture Validated Report, HCDA/AFA. Available Online at: https://www.agriculture

authority.go.ke/wp-content/uploads/2016/09/Horticulture-2015_2016-Validated-Report3.pdf. Accessed 23 May 2018.

He, X., & Zhang, J., 2006 Toward a molecular understanding of pleiotropy. Genetics 173, 1885–1891. (doi:10.1534/genetics.106.060269).

Hossain, M. A., & Rahman, S. M. M. (2011). Total phenolics, flavonoids and antioxidant activity of tropical fruit pine apple. *Food Research International*, 44, 672−676.

Huang, S., Li, R. Q., Zhang, Z. H., Li, L., Gu, X. F., Fan, W., Lucas, W. J., & Wang, X. W. (2009a). The genome of the cucumber, *Cucumis sativus* L. *Nat. Genet.* 41:1275–1281.

Huang Y, Tang R, Cao QL, Bie ZL (2009b) Improving the fruit yield and quality of cucumber by grafting onto the salt tolerant rootstock under NaCl stress. *Sci Hortic-Amsterdam* 122: 26–31.

IPGRI (2003). Descriptors for melon (*Cucumis melo L.*). International Plant Genetic Resources Institute, Rome, Italy.

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2006). Farm management handbook of Kenya, 2nd edition, Volume II: Natural conditions and farm management information. Part C: East Kenya: Ministry of Agriculture/GTZ. Nairobi, Kenya.

Jaetzold, R**.,** Schmidt, H., Hornetz, B., & Shisanya, C. (2010). Farm Management Handbook of Kenya. Gesellschaft für Internationale Zusammenarbeit, vol. 2. Brookpak Printing & Supplies, Nairobi, Kenya.

Jimam, N. S., Wannang, N. N., Omale, S., & Gotom, B. (2010). Evaluation of the hypoglycemic activity of *Cucumis metuliferus* (Cucurbitaceae) fruit pulp extract in norm glycemic and alloxan-induced hyperglycemic rats. *J. Young Pharm.* 2(4): 384–387.

Karaye, I. U., Aliero, A. A., Muhammad, S., & Bilbis, L. S. (2012). Comparative evaluation of amino acid composition and volatile organic compounds of selected Nigerian cucurbit seeds. *Pakistan J. Nutr.* 11(12):1161-1165.

Karp, H. (2013). *Dietary phosphorus sources and their acute effects on mineral metabolism in healthy women*. J Ren Nutr 2013;22:416-422.

Kathayat, K., Rawat, M., Kandpal, G., Pandey, G., & Chauhan, P. (2019). Genetic variability in cucumber (*Cucumis sativus L* .): A review genetic variability in cucumber (*cucumis sativus l* .) : Plant Archives Vol. 18 No. 2, 2018 pp. 1223-1228.

Kaushik, U., Aeri, V., & Mir, S. R. (2015). Cucurbitacins – An insight into medicinal leads from nature. *Pharmacognosy Reviews, 9(17), 12–18.* http://doi.org/10.4103/0973-7847.156314.

Kenya information Guide (2015). Embu County. http://www.kenya-information-guide.com/embu-county.html. Retrieved on 24th March, 2018.

K'opondo, F. B. (2011). Morphological characterization of selected spider plant (*Cleome gynandra L.*) types from western Kenya. *Ann. Biol. Res, 2(2), 54-64.*

Kumar, A. R., Kumar, N., & Kavino, M. (2006). Role of Potassium in fruit crops - a review, Agric. Rev.,*27*(4), 284–291,2006.

Kumar S, Imtiyaz M, Kumar A, Singh R (2007) Response of onion (Allium cepa L.) to different levels of irrigation water. *Agr Water Manage* 89: 161–166

Lim, T. K. (2012). Edible Medicinal and Non-Medicinal Plants. Volume 2, Fruits. Springer, New York.

Lysne, B. (2015). Horned Melon *Cucumis metuliferus*. Online publication: http://msubiology.info/shipunov/school/biol_310/2015_spring/presentations/horned_melon.pdf. Accessed on 16th May, 2018.

Masabni, J., Dainello, F., & Cotner, S., (2011) Texas Vegetable Growers' Handbook. Available at: http:// aggie-horticulture.tamu.edu/publications/veghand-book/index.html (Accessed 27 September 2019).

Martinelli, F., Basile, B., Morelli, G., d'Andria, R., & Tonutti, P., (2012) Effects of irrigation on fruit ripening behavior and metabolic changes in olive. *Sci Hortic-Amsterdam* 144: 201–207.

Marriog, G., & Cheverud, J. M. (2001). A comparison of phenotypic variation and covariation patterns and the role of phylogeny, ecology, and ontogeny during cranial evolution of new world monkeys. *Evolution*, 55, 2576–2600.

Marsh, D.B. 1993. Evaluation of *Cucumis metuliferus* as a specialty crop for Missouri. p. 558-559. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York.

Mcclure, S. T., Chang, A. R., Selvin, E., Rebholz, C. M., & Appel, L. J. (2014). Dietary Sources of Phosphorus among Adults in the, *23*. https://doi.org/10.3390/nu902009.

Mccormack, J. (2005). An organic seed production manual for seed growers. *Cucurbit Seed Production 22936(434), 1–36.*

MoALF (2016a). *Climate Risk Profile for Embu County. Kenya County Climate Risk Profile Series*. The Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

MoALF (2016b). *Climate Risk Profile for Meru County. Kenya County Climate Risk Profile Series*. The Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

MoALF (2016c). *Climate Risk Profile for Makueni County. Kenya County Climate Risk Profile Series*. The Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

MoALF (2016d). *Climate Risk Profile for Kwale County. Kenya County Climate Risk Profile Series*. The Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

MoALF (2016e). *Climate Risk Profile for Kilifi County. Kenya County Climate Risk Profile Series*. The Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

MoALF (2016f). *Climate Risk Profile for Migori County. Kenya County Climate Risk*

Profile Series. The Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

MoLPP (2019). Ministry of Lands and Physical Planning. *Maps & Administrative Boundaries*. Accessed from: https://lands.go.ke/wp-content/uploads/2018/11/The-Map-of-Kenya.pdf Accessed on 30th June 2019.

Motlhanka, D.M.T. (2008). Free radical scavenging activity of selected medicinal plants of Eastern Botswana. *Pak. J. Biol. Sci.* 11:805–808.

Motlhaodi, T., Geleta, M., Chite, S., Fatih, M., Ortiz, R., & Bryngelsson, T. (2009). Genetic diversity in sorghum. Germplasm from Southern Africa as revealed by microsatellite markers and agro-morphological traits. *Genetic Resources and Crop Evolution*: 1-12

Mukhopadhyay, T., & Bhattacharjee, S. (2016). *Genetic Diversity: Its Importance and Measurements*. In Mir A.M. and Nazir Ahmad Bhat N.A. (Eds). Conserving Biological Diversity: A Multiscaled Approach. Research India Publications, New Delhi, India. ISBN: 978-93-86138-00-2.

Munene, A. K., Nzuve, F., Ambuko, J., & Odeny, D. (2018). Heritability Analysis and Phenotypic Characterization of Spider Plant (*Cleome gynandra* L .) for Yield. *Advances in Agriculture*. Volume 2018, Article ID 8568424, 11 pages https://doi.org/10.1155/2018/8568424

Nair, K. M., & Iyengar, V. (2009). Iron content , bioavailability & factors affecting iron status of Indians,*The Indian Journal of medical Research ,130,pp 634–645.*

National Research Council (2008). *Horned melon, p. 89–101. Lost Crops of Africa*. Vol. III: Fruits. The National Academic Press, Washington DC.

Nerdy, B. (2018). Determination of Sodium, Potassium, Magnesium, and Calcium Minerals Level in Fresh and Boiled Broccoli and Cauliflower by Atomic Absorption Spectrometry. *IOP Conference Series: Materials Science and Engineering*, 288(1). https://doi.org/10.1088/1757-899X/288/1/012113.

Noubiap, J. J. N., Bigna, J. J. R., & Nansseu, J. R. N. (2015). Low Sodium and High Potassium Intake for Cardiovascular Prevention : Evidence Revisited With Emphasis on Challenges in Sub-Saharan Africa. *Journal of Clinical Hypertension Volume 17,pp 81–83*. https://doi.org/10.1111/jch.12439

Ojiewo, C. O., Tenkouano, A., and Yang, R. 2010. The role of AVRDC-The world vegetable centre in vegetable value chains. *African Journal of Horticultural Science*, pp3.

Omale, S., Wuyep, N. N., Auta, A., & Wannang, N.N. (2011). Anti-ulcer properties of Alkaloids isolated from the fruit pulp of *Cucumis metuliferus* (Cucurbitaceae). *Journal of Young Pharmacist*, 2 (10): 2586-2588.

Pavlicev, M., & Cheverud, J. M. (2011). Evolution of adaptive phenotypic variation patterns by direct selection for evolvability. *Journal of Young Pharmacists. 2*: 1903–1912. https://doi.org/10.1098/rspb.2010.2113

Rabei, S., Rizk, R. M., & Khedr, A. H. A. (2013). Keys for and morphological character

variation in some Egyptian cultivars of Cucurbitaceae. *Genetic Resources and Crop Evolution*, *60*(4), 1353–1364. https://doi.org/10.1007/s10722-012-9924-5

Raghami, M., López-Sesé, A. I., Hasandokht, M. R., Zamani, Z., Moghadam, M. R. F., & Kashi, A. (2014). Genetic diversity among melon accessions from Iran and their relationships with melon germplasm of diverse origins using microsatellite markers. *Plant Systematics and Evolution*, *300*(1), 139–151. https://doi.org/10.1007/s00606-013-0866-y

Reshmika, P.K., & Sameer, A.M. (2016). Taste a Kiwano Fruit. *e-journal* pp 38–39.

Rosenow D.T. & Dahlberg J.A. (2000). *Collections, conversion and utilization of sorghum. In: Sorghum: origin, history, technology and production.* Edited by Smith CW, Frederiksen RA. New York, USA: John Wiley and Sons, Inc, pp. 309-328.

Rudrappa U. (2019). *Horned melon nutrition facts.* https://www.nutrition-and-you.com/horned-melon-nutrition-facts-and-health-benefits.html. Retrieved on 5th January, 2020.

Sharma, A, Katoch V. and Rana, C. (2016). *Important Diseases of Cucurbitaceous Crops and Their Management*. In Mohammad Pessarakli (Ed): Handbook of Cucurbits Growth, Cultural Practices and Physiology, First Edition, Chapter 18. CRC Press.

Sigüenza, C., Schochow, M., Turini, T., & Ploeg, A. (2005). Use of *Cucumis metuliferus* as a Rootstock for Melon to Manage Meloidogyne incognita. *Journal of Nematology 37(3):276–280. 2005.*

Solmaz. I., Sari. N., Yalcin Mendi. Y., Aka Kacar. Y., Kasapoglu. S., Gursoy. I., Suyum. K., Killi. O., Serce. S. & Yildirim. E., (2010). The characterization of some melon genotypes collected from Eastern and Central Anatolia region of Turkey. IVth International Symposium on Cucurbits, *ISHS Acta Hortic*. 871: 187-196.

Sultana, R. S., & Rahman, M. (2014). Melon crops improvement through biotechnological techniques for the changing climatic conditions of the 21 st century. *International Journal of Genetics and Genomics 2014; 2(3): 30-41* https://doi.org/10.11648/j.ijgg.20140203.11.

Suslow, T., Cantwell, M., & Mitchell, J. (2013) Cantaloupe: *Recommendations for Maintaining Postharvest Quality.* Available at: http://postharvest.ucdavis.edu/pfvegetable/Cantaloupe. Accessed on 31 November 2019.

Tareen, H., Mengal, F., Masood, Z., Mengal, R., Ahmed, S., Bibi, S., & Nawaz, Z. (2016). Determination of Vitamin C content in Citrus Fruits and in Non-Citrus Fruits by Titrimetric method, with special reference to their nutritional importance in Human diet. *Biological Forum - An International Journal*, *7*(2), 367–369.

Thi, T., Anh, T., Khanh, T. D., Dat, T. D., & Xuan, T. D. (2018). Identification of Phenotypic Variation and Genetic Diversity in Rice (*Oryza sativa* L.) Mutants. *Agriculture pp 1–15*. https://doi.org/10.3390/agriculture8020030

Tshilidzi Madzivhandila, Si banda, S., & Gwelo, F. A. (2016). *Achieving Food Security and Nutrition*. Africa Agriculture Status Report 2016, 19.

USDA, (2011) National Nutrient Database for Standard Reference 2011. Available at: www.nal.usda.gov/fnic/foodcomp/search. Accessed on 7 January 2020.

Usman, J. G., Sodipo, O. A., & Sandabe, U. K. (2014). Phytochemical screening and acute toxicity study of *Cucumis metuliferus* E. Mey. Ex. Naudin fruit extract in cockerels. *Internat. Jour. Phytomed.* 6(2):243-247.

Usman J. G., Sodipo, O. A., Kwaghe, A.V, & Sandabe, U. K. (2015) Uses of *Cucumis metuliferus:* A Review. *Cancer Biology* 5(1):24-34]. (ISSN: 2150-1041). http://www.cancerbio.net.

Varshney, R. K., Mahendar, T., & Aggarwal, R. K. (2007). Chapter 2 Genic Molecular Markers in Plants: *Genomics*, *1*, 13–29. https://doi.org/10.1007/978-90-481-2967-6

Volis, S., and Blecher, M. 2010. Quasi in situ: a bridge between ex situ and in situ conservation of plants. *Biodiversity and Conservation*, 19(9), 2441-2454

Wannang, N. N., Kwanashie, H.O., Ede, S.O. (2010). Antiviral activity of the fruit extract of *Cucumis metuliferus* E. Meye (Curcubitaceae) in chicks. *Afr. J. Basic and Appl. Sci.* 2(2-4):89-93.

Wannang, N. N., Gyang, S. S., Omale, S., Dapar, L. M. P., Jiman, N. S. & Anakwe, C. (2009). The effect of *Cucumis metuliferus* E. Meye (Cucurbitaceae) on rat gastric functions and mucosal integrity. *Nig. J. Nat. Prod. and Med.* 12: 37-39.

Wannang, N. N., Jiman, N. S., Gyang, S. S., Bukar, B. B. & Gotom, S. (2008). Effects of *Cucumis metuliferus* E. Mey. Ex. Naud. (Cucurbitaceae) fruit extract on some male reproductive parameters in adult rats. *Afr. J. Phar. and Pharmacol.* 2(3):48- 51.

Wannang, N. N. (2011). Aqueous Fruit Extract of *Cucumis metuliferus* E Mey. Ex Naud (Cucurbitaceae) Alters Behavioral Activities in Chicks. *PAT* 7 (1): 84-89 ISSN: 0794-5213.

Walters, S.A. & Wehner, T.C. (2002). Incompatibility in diploid and tetraploid crosses of *Cucumis sativus* and *Cucumis metuliferus*. *Euphytica* 128(3):371-374.

Walters, S. A., Wehner, T.C., Daykin, M.E., & Baker, R. B. (2006). Penetration rates of root knot nematodes into *Cucumis sativus* and *C. metuliferus* roots and subsequent histological Changes. *Nematropica 36:231–242*.

Wang, Y. H., Joobeur, T., Dean, R. A., & Staub, J. E. (2007). Cucurbits Genome Mapping and Molecular Breeding in Plants. *Nature Genetics*, 41: 1275–1281.

Weaver, C. (2013). White Vegetables : A Forgotten Source of Nutrients Potassium and Health 1 – 3. *American Society for Nutrition*, *4*, 3685–3775. https://doi.org/10.3945/an.112.003533.smoking

Welman, M. (2009). *Cucumis metuliferus*. South Africa National Biosafety Institute. Available online: http://www.plantzafrica.com/planted/cucumismet.htm. Accessed on 15th March 2018.

Weng, Y. (2010). Genetic Diversity among *Cucumis metuliferus* Populations Revealed by Cucumber Microsatellites, *HortScience* 45(2), 214–219.

Wilberforce, J. O. (2016). Using Refractometer to Determine the Sugar Content in Soft Drinks Commonly Consumed In Abakaliki, Nigeria. *Journals of Applied Chemistry* 7: 89–91. https://doi.org/10.9790/5736-0907018991.

Wilkins-Ellert, M.H., (2004). *Cucumis metuliferus* E.Mey. Ex Naudin. [Internet] Record from PROTA4U. Grubben, G. J. H. & Denton, O. A. (Editors). PROTA (Plant Resources of Tropical Africa / Resources végétales de l'Afrique tropicale), Wageningen, Netherlands. <http://www.prota4u.org/search.asp>. Accessed 18 February 2018.

Willmore, K.E., Young N.M. and Richtsmeier, J. T. (2007). Phenotypic Variability: Its Components, Measurement and Underlying Developmental Processes. Evolutionary Biology, https://doi.org/10.1007/s11692-007-9008-1

Yagi, K., Siedlecka, E., Pawełkowicz, M., Wojcieszek, M., Przybecki, Z., Tagashira, N., Hoshi, Y., Malepszy, S. & Pląder, W. (2014). Karyotype Analysis and Chromosomal Distribution of Repetitive DNA Sequences of *Cucumis metuliferus* Using Fluorescence in situ Hybridization. *Cytogenet Genome Res 2014; 144:237-242.*

APPENDICES

Appendix 1: Descriptors for Melon

Note	Descriptor name	Descriptor state	Note
Plant			
1	Plant growth habit	1. Bushy 2. Runner	
2	Main vine length		To be measured in cm at maturity.
3	Number of branches on the main vine		To be counted along the main vine at maturity
4	Leaf blade	3. Shallow 5. Medium 7. Deep	Depth of incisions of margin of leaf of central third of plant.
5	Leaf Shape	1. Entire 2. Trilobate 3. Pentalobate 4. 3-palmately lobed 5. 5-palmately lobed 99 Other (specify)	
Flower			
6	Hermaphroditic flowers	0. Absent 1. Present	
7	Corolla colour	1. Deep-yellow 2. Light-yellow	
Fruit			
8	Fruit Number		To be counted per plant at harvest
9	Fruit weight (Kg)		To be measured at physiological maturity
10	Fruit shape	1. Pyriform 2. Cylindrical 3. Flattened 4. Elliptic 5. Broad elliptic 6. Round	
11	Predominant fruit skin colour (Background)	1. Brown 2. White 3. Dark green 4. Medium green 5. Yellow 6.. Light green 99 Other (specify)	

12	Design produced by secondary skin colour (Colour pattern)	0. No 2^0 skin colour 1. Solid 2. Stripped 3. Spotted 4. Mixed 99 Other (specify)	Colour pattern of fruit skin
13	Skin stripe colour	1. None 2. Light green 3. Medium green 4. Dark green 5. White 6. Yellow 7. Brown 99 Other (specify)	
14	Flesh colour	1. Red 2. Pink 3. Yellow 4. White 5. Mixed 6. Orange 7. Green 99 Other (specify)	Colour of ripe fruit flesh
15	Flesh Taste	1. Sweet 2. Bland 3. Bitter	
16	Thickness of outer layer of pericarp	1. Thick (20-24mm) 2. Medium (10-19mm) 3. Thin (<10mm)	Measured in mm at physiological ripeness.
17	Grooves	0. Absent 1. At basal half 2. At apical half 3. On whole fruit	
Seed			
18	Seed Size	1. Very small (<5 mm) 2. Small (5-8 mm) 3. Intermediate (9-12 mm) 4. Large (13-16 mm) 5. Very large (> 16 mm)	
19	Seed Shape	1. Roundish (length/width <2.0) 2. Elliptical (length/width between 2 and 2.5) 3. Oval (length/width >2.5) 4. Triangular 5. Pinonet type (like pine seeds) 99 Other (specify)	
20	Predominant Seed	1. White	

	Colour	2. Light Brown or Tan 3. Brown 4. Dark Brown 5. Black 99 Other (specify)	
21	Number of seeds per fruit	1. Low (<10) 2. Intermediate (10-100) 3. High (>100)	
Other Agronomic Aspects			
22	Days to Emergence		No. of days from sowing to when the seedling emerges
23	Days to first flower		No. of days from sowing to when the first flower opens
24	Days to first female flower		No. of days from sowing to when the first female flower opens
25	Maturity Period	1. Early (<70 days) 2. Intermediate (70-90 days) 3. Late (91-110 days) 4. Very late (>110 days)	No. of days from sowing to when the fruit ripens
26	Disease resistance	1. Highly resistant 2. Resistant 3. Moderately Resistant 4. Susceptible 5. Severely Diseased	
27	Pest resistance	1. Highly resistant 2. Resistant 3. Moderately Resistant 4. Susceptible 5. Highly susceptible	
28	Non-pathogenic disorders	1. Highly resistant 2. Resistant 3. Moderately Resistant 4. Susceptible 5. Highly susceptible	

Source: Jarret and Griffin, 2007; IPGRI, 2003

Appendix 2: Determination of the moisture content (Nerdy, 2018)

a) Method

1. The empty dish and lid was dried in the oven at 105ºC for 3 hours then transferred to the desiccator to cool. The empty dish and lid was then be weighed.
2. About 3g of sample was spread then weighed to the dish
3. The dish with the sample was placed in the oven then dried for 3 hours at 105ºC
4. The dish with partially covered lid was transferred to the desiccator to cool.
5. The dish and the dried sample was reweighed.
6. Calculate the moisture content on a wet-weight basis using the following formula:

$$\text{Moisture content (\%)} = \frac{W2 - W3 \times 100}{W2 - W1}$$

Where,

W1 = weight of container with lid;

W2 = weight of container with lid and sample before drying; and

W3 = weight of container with lid and sample after drying.

Appendix 3: Determination of Sugar content using Brix refractometer(Cadet, 2014)

Procedure:

1. 25ml of the fruits sample was centrifuged for 10 minutes
2. 15ml of the clear sample was placed in clean beakers.
3. Well calibrated and clean brix was then used. Cleaning was done using pure water and calibration was done using pure water.
4. Few drops of the liquid are then dropped on the slide using a dropper then the flip was covered and left to stabilize.
5. The readings were then taken through the eye piece focus under the ray
6. Analysis were then done in triplicates

Appendix 4: Determination of Vitamin C (Ascorbic Acid) (Tareen *et al.*, 2016)

a) Reagents

i) Standard Indophenol Solution

ii) Standard Ascorbic acid solution

iii) Metaphosphoric acid - 20 %

iv) Acetone

b) Procedure

Pipette 50 mL of unconcentrated juice (or the equivalent of concentrated juice) into a 100 mL volumetric flask, add 25 mL of 20% metaphosphoric acid as stabilizing agent and dilute to volume. Pipette 10 mL in a small flask and add 2.5 mL acetone. Titrate with indophenol solution until a faint pink colour persists for 15 seconds.

c) Calculation

Vitamin C (mg/100mL juice) = 20 (X) (C)

Where,

X = mL indophenols solution,

C = Vitamin C per mL indophenol solution

Appendix 5: Determination of Phosphorus content (Consoli & Camargo, 2015)

a) Preparation of the ash solution

1. To prepare the ash solution, 10 g of sample was burned in a furnace at 550°C.
2. 5 ml of concentrated nitric acid was added to the obtained ash and the mixture was boiled for 5 min on a hot plate.
3. Nitric acid was added to maintain the volume in initial amount. Solution was transferred into a container and 40 ml distilled water was added then boiled for 10 min. After cooling 100 ml of ash solution was prepared in a flask.

b) Measuring Phosphorous

1. Spectrophotometric method was used to measure phosphorus.
2. For this purpose, 5 ml of ash solution was transferred to a 100 ml volumetric flask then 25 ml of vanadate - molybdate reagent was added and solution was made up to 100 ml.
3. After 10 minutes' relaxation, absorbance of the solution determined at the 420 nm wavelength against blank sample.

Appendix 6: Determination of Na and K using flame photometer (Nerdy,2018)

Instruments, reagents and glassware

1. Flame photometer FLAPHO.
2. Glass pipettes: 1, 2, 10 ml.
3. Stock solutions of Na+ and K+, c = 1 mg/ml.
4. 6 numbered 100 ml volumetric flasks.

Preparation of standard solutions

Standard solutions were prepared by dilution of stock solutions. Different glass pipettes and numbered 100 ml volumetric flasks were used to prepare the solutions as follows:

Flask No	**1**	**2**	**3**	**4**	**5**	**6**
Volume of the pipette to use	1	1	2	10	10	10
Volume of Na stock solution to pipette	0.5	1	2	4	6	8
Volume of K stock solution to pipette	0.5	1	2	4	6	8
Concentration of solution obtained	5	10	20	40	60	80

Sample preparation

Test solution was given in 100 ml flask which was filled up to the mark with distilled water and mixed.

Measurement

1. The instrument was warmed up for 5-10 minutes then filled with distilled water
2. Aspirate the most concentrated standard solution (solution number 6)
3. Aspirate distilled water – the instrument should read
4. Aspirate standard solutions no. 1, 2, 3, test solution, and then standards 4, 5, 6.
5. Record the results.
6. Repeat 3-7 for solutions of potassium.
7. Aspirate distilled water for at least 5 minutes to clean the system

Appendix 7: Determination of Iron content (Nerdy, 2018)

Preparation of the standards

The standards was prepared by using iron nitrate which was prepared to 0.001M. The 0.001M was then used to prepare different concentrations by measuring 5ml, 10ml, 15ml and 20ml into different test tubes.

To test tube 1, no iron nitrate was added. To test tube 2, 5ml was added, and to test tube 3, 5, and 5, 10ml, 15ml, and 20ml was added consecutively. To test-tube 1, 20ml of 0.1M HCl was added. To test tube 2, 3, 4 and 5, distilled water was added 15ml to test tube 2, 10ml to test tube 3, 5ml to test tube 4 and none to test tube 5. 2.5ml of 0.1M KCSN was added to each test tube which to form a red colour to confirm formation of $FeSCN^{2+}$ ion.

Preparation of the plant sample

Preparation of the plant samples 2.5g of the plant samples was weighed and placed into a crucible.

The crucibles was then heated with a hot burner flame until the food sample turned to ash. The time for heating was 20 minutes.

The burner was removed and the samples were allowed to cool. They were transferred to small beakers.

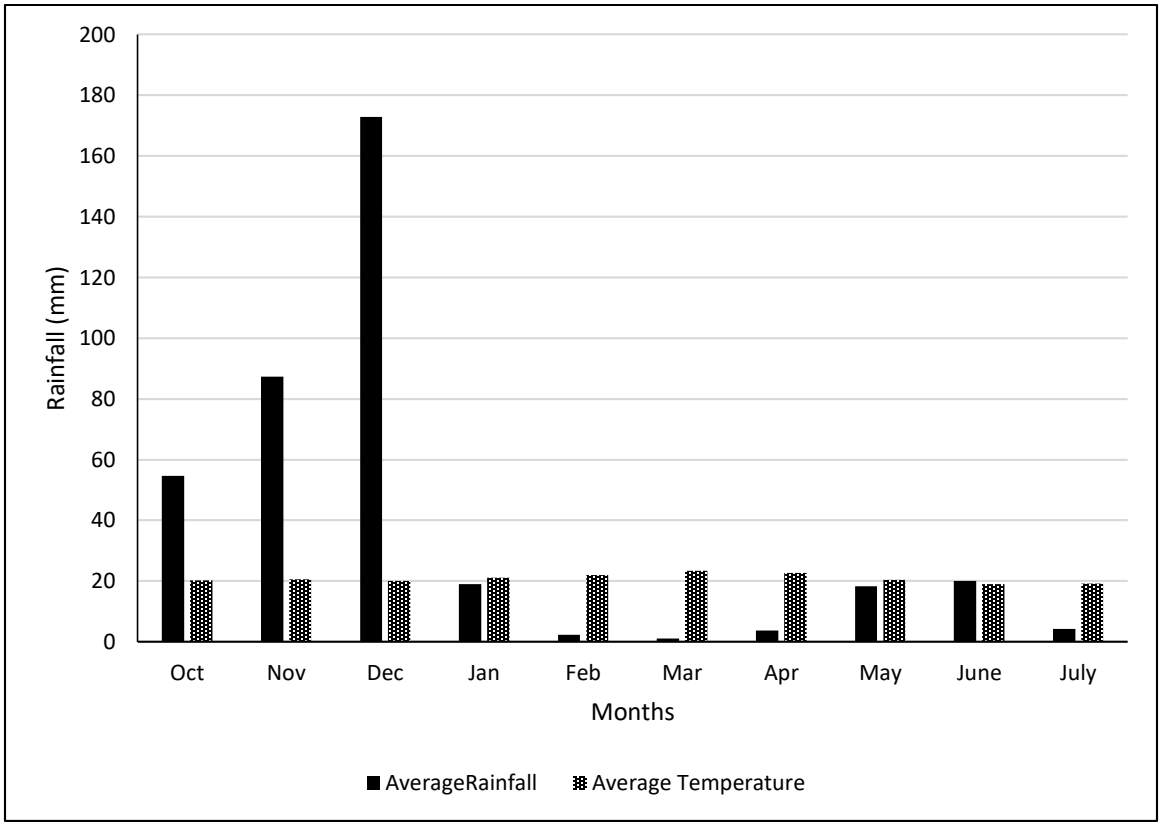
10ml 0f HCl was carefully added to the beakers and stirred to the beakers too and mixing was well done. The was then filtered to collect the filtrate. 2.5ml of 0.1 KCSN was added to each filtrated.

Finding the absorbance

A wavelength of 458nm was used in the UV-Vis. The standard solutions was then placed in different curettes and also plant samples in different curettes. The absorbance was then measured and recorded.

Data analysis A standard curve (Beers law) of the standard concentrations verses absorbance was used to find the concentrations of the plant samples.

Appendix 8: Rainfall Received at the Site from October 2018 to July 2019



Appendix 9: ANOVA Tables

a. Quantitative traits for combined seasons

Table 1: Analysis of variance (Main Vine Length):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	13105.605	354.206	0.612	0.949
Error	76	44000.000	578.947		
Corrected Total	113	57105.605			

Table 2: Analysis of variance (Branch No):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	118.308	3.198	0.511	0.987
Error	76	475.447	6.256		
Corrected Total	113	593.755			

Table 3 Analysis of variance (Fruit No.):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	985.255	26.629	2.033	**0.005**
Error	76	995.429	13.098		
Corrected Total	113	1980.683			

Table 4 Analysis of variance (% germination):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	20519.939	554.593	3.192	**< 0.0001**
Error	76	13204.667	173.746		
Corrected Total	113	33724.605			

Table 5 Analysis of variance (Days to emergence)					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	61.965	1.675	6.159	**< 0.0001**
Error	76	20.667	0.272		
Corrected Total	113	82.632			

Table 6 Analysis of variance (Days to male flowering)					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	3051.333	82.468	17.125	< **0.0001**
Error	76	366.000	4.816		
Corrected Total	113	3417.333			

Table 7 Analysis of variance (Days to female flowering)					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	2539.333	68.631	16.789	< **0.0001**
Error	76	310.667	4.088		
Corrected Total	113	2850.000			

Table 8 Analysis of variance (Days to maturity)					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	6011.333	162.468	15.095	< **0.0001**
Error	76	818.000	10.763		
Corrected Total	113	6829.333			

Table 9Analysis of variance (Fruit weight):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	46672.351	1261.415	1.012	0.470
Error	76	94686.667	1245.877		
Corrected Total	113	141359.018			

Table 10 Analysis of variance (Seed size):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	9.500	0.257	7.457	**< 0.0001**
Error	76	2.617	0.034		
Corrected Total	113	12.117			

Table 11 Analysis of variance (Rind thickness):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	37.897	1.024	10.372	**< 0.0001**
Error	76	7.505	0.099		
Corrected Total	113	45.402			

b. ANOVA for nutritional composition for combined seasons

Table 12 Analysis of variance (percentage moisture content):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	297.383	8.037	2.239	**0.002**
Error	76	272.758	3.589		
Corrected Total	113	570.140			

Table 13 Analysis of variance (Sugar):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	48.695	1.316	37.953	< **0.0001**
Error	76	2.635	0.035		
Corrected Total	113	51.331			

Table 14 Analysis of variance (Potassium):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	119666.566	3234.232	8.944	< **0.0001**
Error	76	27482.880	361.617		
Corrected Total	113	147149.446			

Table 15 Analysis of variance (Sodium):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	10.964	0.296	2.487	**0.000**
Error	76	9.056	0.119		
Corrected Total	113	20.020			

Table 16 Analysis of variance (Iron):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	68.496	1.851	31.598	< **0.0001**
Error	76	4.453	0.059		
Corrected Total	113	72.948			

Table 17 Analysis of variance (Vitamin C):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	0.305	0.008	1.210	0.239
Error	76	0.518	0.007		
Corrected Total	113	0.824			

Table 18 Analysis of variance (Phosphorus):					
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	37	12909.254	348.899	30.178	< **0.0001**
Error	76	878.665	11.561		
Corrected Total	113	13787.918			