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MORPHOLOGICAL AND GENETICAL DIVERSITY OF MANGO (Mangifera indica L.) CULTIVARS IN SHENDI AREA

BY

Zeinab Mohammed Ahmed Mohammed

B.Sc (Agric)

Sudan University of Science and Technology (2001)

A thesis Submitted to University of Shendi in Fulfillment of the Requirement for the Degree of M.Sc in Plant Biotechnology

Supervisor: Prof. Tagelsir Hassan Mohamed Ahmed

Dec. 2014

Shendi

بسم الله الرحمن الرحيم

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بِسْمِ اللهِ الرَّحْمَن الرَّحِيمَ

قَالَ تَعَالَى:-

(وَهُوَ الَّذِي أَنْشَأَ جَنَّاتٍ مَعْرُوشَاتٍ وَغَيْرَ مَعْرُوشَاتٍ والنخل وَالزَّرْع مُخْتَلِفًا أَكْلُهُ وَالزَّيْتُون وَالرُّمَان مُتَشَابِهًا وَغَيْرَ مُتَشَابِه كُلُوا مِنْ ثَمَرِهِ إِذَا أَثْمَرَ وَءاتَوْا حَقَّهُ يَوْم حصَادِه وَلَا تُسْرِفُوا إِنَّهُ لايحب المُسْرِفِينَ).

الآيَةُ (١٤١) سُورَة الانْعَامِ.

Dedication

To my husband

Amir Elhashmi

&

My sister

Amna

Acknowledgement

I wish to express my sincere thanks and gratitude to my supervisor, Prof. Tagelsir Hassan Mohamed Ahmed for his encouragement, endless guidance, valuable comments, advises and support during the course of this study. I am greatly indebted to him.

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ABSTRACT

This study was performed to identify mango cultivars in Sudan based on their morphology and genetic. Leaves and fruits were collected in triplicate representing 30 cultivars. Sixteen cultivars were grafted genotypes of Indian or Egyptian origin, Eleven cultivars were grown directly from seeds (Balady) and 3 cultivars imported recently from South Africa. IPGRI (2006) descriptors were used in the study. Comparisons between means were made by least significant differences (LSD). The result showed a high diversity of mango genotypes and cultivars. There were great variations in leaf length, Width and petiole length with significant ($P \leq 0.05$) differences between the genotypes and cultivars in each genotype. Seedling cultivars showed longer leaves ($\geq$ 20cm) compared to the South African and grafted cultivars which showed a wide range of leaf length. Leaf width followed the same trend as the leaf length. Petiole length showed significant differences ($P \leq 0.05$) between the three genotypes but not between cultivars in each of them. Leaf margin and texture vary greatly between cultivars with no dominant shape among any of the three genotypes. The inflorescence lengths vary significantly ($P \leq 0.05$) between genotypes and cultivars with averages of 34.6, 24.2 and 23.3 cm for the seedling, Grafted and South African cultivars respectively. The color, shape, density and floral leaves of the inflorescence of mango cultivars vary greatly. Mango fruits showed significant ($P \leq 0.05$) differences in size, weight and circumferences depending on the cultivar.

The length ranged between 7.9 to 20.1 cm, the width 6.1 to 11.6 cm, the weight between 195.7 to 1154.4 gm and 19.6 to 36.9 cm for the circumference. The fruit shape, apex shape and slope of shoulder were also variety characteristics. No significant differences were observed between cultivars regarding fruit beak type and sinus type. The fruit skin weight percentage vary greatly between cultivars

ranging between 9.6 and 19.7 % with yellow or green colors. The weight texture and color of the pulp was genotypes dependant. The pulp fiber content showed great variations in quantity and quality of mango cultivars with a range of 7.0 to 45% fiber weight percentage. The seed length, width, thickness and weight percentage vary between cultivars and were proportional to those of the fruit. Mango varieties were amplified using 4 different Operon RAPD primers. The primers were OPC9, OPL18, OPR10 and OPY14.The 4 RAPD primers used in this study were found to be poly morphic with mango cultivars tested. A total of 175 fragments were detected for the eleven samples representing 24 different loci with 91.7% polymorphism. Variety Ras maktoul and Sinaria produced no fragment with primer OPR10 where as Bizeret Shendi and Shabala produced no fragments with OPY 14 and OPL 18 respectivly. - The Similarity indices were calculated using Jaccard's coefficient.- The most relative varieties were Kutchineer and Taiba with 87% similarity; while the most distant were Bet bady and Wad srear with similarity percentage of 4% . According to the similarity indices, the 11 samples were grouped into four clusters. Among these, variety Bet bady and variety Shabala were each grouped in separate clusters (clusters 3 and 4), varieties Bizrt shendi and Ras maktoul were grouped together in Cluster 2 while all of the other varieties were included in Cluster 1.

ملخص البحث

التنوع المورفولجي والوراثي لاصناف المانجو بمنطقة شندي

الخصائص المورفولوجيه والوراثيه لها الدور في تحديد الاختلافات بين اصناف المانجو لانه من الصعب تحديد الصنف في المراحل الاولي للنمو. وقد اجريت هذه الدراسه بمنطقة شندي بهدف تحديد وتوصيف اصناف المانجو مورفولوجيا ووراثيا و تم اختيار ثلاثون صنفا من المانجو منها ستة عشر صنفا من الاصناف المطعومه وهي من اصل هندي او مصري واحدي عشر من الاصناف المحليه وثلاثة اصناف مستوردة من جنوب افريقيا. تم تحليل النتائخ باستخدام برنامج الاحصاء التحليلي وملاحظة الفروقات ذات الدلاله الاحصائيه (LSD). اثبتت الدراسة ان هنالك نتائج واختلافات كبيره بين اصناف المانجو من حيث طول الورقه وعرضها وطول العنق وكانت الاختلافات بين الانماط الجينيه والاصناف الوراثيه . الاصناف المحليه اوراقها طويله اكبر من 20سم مقارنه مع الاصناف المطعومه واصناف جنوب افريقيا وايضا العرض . طول العنق اظهر فروقات معنويه بين الانماط الجينيه الثلاثه وليس بين كل صنف وكذلك حافة الورقه وملمسها . كما اثبتت الدراسة الفروقات المعنويه ($P \leq 0.05$) بين الانماط الجينيه الثلاثه . ايضا توجد فروقات معنويه ين لون النوره وشكلها وكثافتها ووجود الاوراق بها و طول و عرض ووزن الثمار. وهنالك خصائص متنوعه في الشكل والحافه والكتف ولم يلاحظ اي فروقات بين الاصناف لنوع المنقار وتجويف ثمار المانجو. هنالك اختلافات كبيره بين الاصناف في وزن قشرة الثمار واللون وزن اللب وملمسه ولونه تختلف البذور من ناحية الطول والعرض والسمك والوزن بين الاصناف ومتناسبه مع الثمرة. تمت دراسة التشابه الوراثي بين الطرز الوراثيه علي المستوي الجزيئي بطريقة الحمض النووي المتباين المتضاعف عشوائيا واستخدمت اربعه من بادئات تضاعف الحمض وتم الكشف علي 175شظايا ل 11 عينه تمثل 24 مواضع مختلفه متعددة الاشكال بنسبة 91.7% . الاصناف راس مكتول وسناريه لم تظهر له شظايا في (OPR10) وايضا بذرة شندي وشباله في (OPL18 – OPY14) علي التوالي وتم حساب نسبة التشابه وكانت الاصناف الاكثر تشابه كتشنير وطيبه بنسبة 87% واقل نسبة تشابه 4% بين بت بادي وودسرير ومن خلال الرسم الشجري لتوضيح العلاقة بين الطرز الوراثيه قد اظهرت اربعه مجموعات بت بادي وشباله في المجموعات 3- 4 علي التوالي وبذرة شندي وراس مكتول في المجموعه 2 وبقية الاصناف في المجموعه 1 .

Chapter 1
INTRODUCTION

Mango (*Mangifera indica L.*) is one of the most important fruit crop grow in the tropics and subtropics. Through the ages, the mango has been acknowledged as an excellent fruit (Singh, 1960). Native to Southern Asia, especially Eastern India, Burma and the Andaman Island, the mango has been cultivated for more than 4000 years (Morton, 1987). The genus Mangifera is one of 173genera belonging to the family Anacardiaceae in the order Sanpindales. Budhwar (2002) stated that the family Anacardiaceae consists of sixty – four genera, mostly trees and shrubs, often containing milky or acid juice, some of which are even poisonous.

Mango is distributed from India to the rest of the tropical and subtropical regions of the world. Major producers of mango are India, Pakistan, Indonesia, Maxico, South Africa, Egypt, United state and Sudan. Maxico is the largest exporter of mangoes in the world (Morton, 1987).

Mango was introduced to Northern Sudan at the beginning of the 20th century, directly from India and from Egypt. Egypt introduced budded plants of mango from Bombay first in 1825 (Singh, 1960). Mr. Bevan, the first man who introduced mango to Shendi Horticultural Department during 20s of the last century. Later Mr. Thrower imported 32 cultivars from Egypt in 1942 in pots as mother trees. Those cultivars were propagated and planted in their permanent sites in 1964. Then they are propagated and distributed to other parts of the Sudan. Abusamaka cultivar is propagated and produced in high number and its cultivation is widely spreading in Blue Nile and Sennar states. (1990s) some cultivars like Tommy aktinz, Elkeitt, Elkent, Sensation and others have introduced by Ministry of sAgriculture and some grower.

In the 1960's little was known about mangoes outside the tropics and there was virtually no international trade involving fresh fruit (Litz, 1997). Today mangoes

are the fifth most important fruit crop, following citrus, banana, grape and apple. In 2002 the world export market for fresh and processed mango fruits had a value of US$ 396 700 000 (FAO, 2002). In 2008 mangoes comprised nearly 40% of the global tropical fruit harvest that was estimated at over 82.7 million ton (MT) (FAO, 2009; FAO, 2010).

Mango has a great economic value; it is the third horticultural product in the international trade. The mango is purportedly the most widely consumed fresh fruit in the world, with worldwide production exceeding 17 million metric tons a year (FAO, 1993). The increase in mango production worldwide can be attributed mainly to the green revolution, which through the use of Mendelian inheritance principles of crop breeding has brought additional supply of staple food as well as horticultural crops to developing countries. Furthermore, this rise in productivity is also due to optimization of agronomical and horticultural field practices and better control of pests and diseases. Mango because of its long juvenile period and heterogeneity, has taken advantages of these technologies. This is reflected in an extension of new planting areas, planting of regular bearing cultivars, control of flowering, irrigation management, fertilization and use of agrochemicals (Mukherjee, 1997). Genetic markers are recognized as one technique that increased the advance in mango improvement as well as the other classifiable methods such asharmonised open pollination and clonal selection (Iyer and Dinesh, 1997).

The study will include morphological and molecular characterization of 30 mango varieties from Sudan. Morphological characterization is traditionally the most common method used and many different crops have been studied (IPGRI, 2006; Gonzalez et *al*., 2002) such as mango (I11oh and Olorode, 1991; Jintanawong *et al*., 1992; Subed *et al*., 2009).

Molecular characterization encompasses modern methods that complement Morphological descriptors and has become quite popular, each with its own advantages and disadvantages (Lavi *et al*., 1993). Studies in *Mangifera indica* L.

have been conducted using different molecular markers Techniques used include random amplified polymorphic- DNA (RAPD (Karihaloo *et al*., 2003; Schnell *et al*., 2004), restriction fragment length polymorphism (RFLP) (Eiadthong *et al*., 1992; Chunwongse *et al*., 2000;Ravishankar *et al*., 2004), amplified fragment length polymorphism (AFLP) (Eiadthongand Yonemori, 2000; Hautea *et al*., 2001; Kashkush *et al*., 2001; Teo *et al*., 2002;Yamanaka *et al*., 2006), microsatellites or simple sequence repeats (SSRs) (Eiadthong *et al*., 1999; Duval *et al*., 2005; Honsho and Nishiyama, 2005; Schnell *et al*., 2005) and inter-SSRs (González *et al*., 2002; Pandit *et al*., 2007; Xian-Mei and Cheng-Xiang, 2007).

The main objectives of this study were to describe and evaluate the main plant and fruit characteristics of 30 varieties from Sudan. The specific objectives were to:

a. Determine the genetic relationship and diversity among 30 mango cultivars using morphological characterization.
b. Determine the genetic relationships and diversity in the cultivars using molecular markers (RAPD).
c.To see extend the genetic relationships revealed by molecular characterization agree with those based on morphological characters.

Chapter 2

LITERATURE REVIEW

2.1Mangoes

The mango (*Mangifera indica L.*) is one of the most important horticultural crops worldwide. Mangoes are a member of the *Anacardiaceae* family that comprises 73 genera, fitted in the order Sapindales. Thisorder belongs to the sub-class Rosidae from the class Magnoliopside and division Magnoliophyta (Bompard and Schnell, 1997; Anonymous, 2008)

With 700 species the genus mangifera to which mangoes belong consists of 69 species and is classified into tow Sub-genera with several sections based on morphological characters. Among the species,*M. indica* is the most important, although there are other species that also produce edible fruit such as *M .altissimaBlanco,M. Lagenifera Griff., M. macrocarpa Blume. M. odorata Griff* and *M. sylvatica Roxb*. (Bompard, 1993). Budhwar (2002) stated that the family *Anacardiaceae* consists of sixty four genera, mostly trees and shrubs, often containing milky or acid juice, some of which are even poisonous. *Anacardiaceae* is a family of mainly tropical species with a view representative in temperate region (Bompard and Schnell, 1997). Over 1,000 known mango cultivars are derived from two strains of mango seed – monoembryyonic (single embryo) which hails from Indian strain of mango and polyembryonic (multiple embryo) from the Indochinese strain. (Fivaz, 1998).

The mango trees is an erect , branched ever green plant ranging from 8 to 40 meters in height depending on the cultivar, climate, soil type and root stock (Gibbon and pain 1985, Fivaz, 1998). Mango trees grown from seeds have long straight stemmed whereas the grafted trees are relatively dwarf and spreading.

The root system of mango trees is composed of a tap root about 6-8m deep, super facial feeder –roots and fibrous anchor roots, sometimes feeder ,roots can develop above the water table and fibrous roots may extend away from the drip line. This effective root system can reach 7.5 m to the lateral side and 1.2 m depth in 18 years or older plants in well-drained soil (Anonymous, 2008). The volume of feeder roots of mango varies during the annual cycle, with the majority of root development occurring during the wet periods of the year and declining during the dry periods. Root growth is periodical, slowing or stopping throughout major canopy growth periods (Bally, 2006).

The leaves of atypical mango tree may be about 4 to 12 inches in length and ¾ to 2 inches in width. Leaves are borne mainly in rosettes at the tips of the branches and numerous twigs from which they drop like ribbons on slender petioles 2.5 – 10 cm long (Morton,1987). The new leaves, appearing periodically and irregularly on a few branches at a time, are yellowish , pink , deep rose or wine red, becoming dark green and glossy above , lighter beneath. The midrib is pale and conspicuous with many horizontal and distinct veins.

The mango inflorescence and romomoeciuos, i.e. each inflorescence bears both hermaphrodite and male flowers in the same panicle. The flowers are usually yellowish or reddish in color and are borne in profuse, showy, erect, pyramidal, and branched clusters in the panicle. The size of both the staminate and hermaphrodite flowers varies from about ¼ to ½ inches in diameter (Morton, 1987). Staminate flowers 25 – 98% of hundreds and even as many as 3.000 to 4.000 small, yellowish or reddish flowers, the rest flowers are hermaphroditic, which borne in profuse, showy, erect, pyramidal, branched clusters (6-40cm) high (Fivaz, 2006).

According to Singh (1968) mango trees have limited fruit production, since only 0.01% is transformed in to fruits, mango pollen has an oblong shape when dried

and spherical when hydrated and each anther can produce between 250-650 grains of pollen. Pollen viability is more prominent immediately after anther opening. High temperatures are favorable for pollen viability and low temperatures cause abnormal pollen production. According to Genu and Pinto (2002) the reduced number of fertilized flower is provoked by the small number of perfect flowers that have been pollinated and due to the large number of male flowers.

Mango fruit have great variation in the form, size, shape, weight, flesh and skin color and quality. The fruit are nearly round, oval, ovoid – oblong, or somewhat kidney – shaped, often with a break at the apex , and are usually more or less lop – sided . Fruits was found to be range from 2 ½ to 10 in (6.25-25 cm) in length and 1.8-2.26 Kg in weight. The skin is leathery, waxy, smooth, fairly thick, aromatic and ranges from light or dark – green to clear yellow, yellow-orange, yellow and reddish – pink , or more or less blushed with bright, dark – red or purple – red, with fine yellow, greenish or reddish dots, and thin or thick whitish, gray or purplish bloom, when fully ripe. (Lakshminarayana, 1980, Morton 1987). Fruit color at maturity is genotypes dependent. The meso - carp can be fibrous or fiber free with flavor ranging from turpentine to sweet (Mukherjee, 1997). The flesh of a mango is peak-like and juicy, with more or less numerous fibers radiating from the husk of a single large kidney-shaped seed. Fibers are more pronoused in fruits grown with hard water and chemical fertilizers. (Morton, 1987).

There is a single, longitudinally ribbed, pale yellowish-white, woody stone, flattened, oval or kidney-shaped, sometimes rather elongated. Stone has along one side a beard of short or long fibers clinging to the flesh cavity, or it may be nearly fibreless. Within the stone is the starchy seed, either monoembryonic or polyembryonic. (Morton, 1987). The seed of mango is solitary, large and flat, ovoid oblong and is surrounded by the fibrous endocarp at maturity. The testa is

thin and papery (Mukherjee, 1997). The seed may fill stone partially or completely (Nair, 1994).

2.1.1 Origin and distribution

According to history, the emperor Akbar, who reigned in Northern India, from 1556 to 1605, planted an orchard of a hundred thousand mango trees. Because of the phyto-geographical distribution of related species, the fossil records and the presence of plenty of wild and cultivated varieties in India, it was stated that the origin of mango was most likely Indo- Burma.

From here mangoes were probably exported to other countries and continents (Singh, 1968, Kostermans and Bompard, 1993).

Mango has been cultivated in India for over 4,000 years or more and then spread to all parts of the tropical world , the Indians took mangoes to Malaya and east Asian countries in the 4^{th}or 5^{th} century and to west Africa , Brazil and the new world by Portuguese in the 18^{th} century (Morton, 1987).

Today the production areas for mango fruits can be grouped into different groups Viz. Florida (USA), Mexico ,central America ,west India (Caribbean Island), South America, Africa/ Arabian Peninsula, Indian subcontinent and Indochina (China /Indonesia /pacific) (Anonymous, 2008).

Jekayinfa and Durowju, (2005) reported that genus mangifera originates in tropical Asia, with the greatest number of species found in Burma, Java and the Malaya. The most- cultivated Mangifera species, *M. indica* (mango), has its origins in India and Myanmar. Mango is now cultivated throughout the tropical and Sub-tropical world for commercial fruit production as a garden tree and as a shade tree for stock.

2.1.2 World production

Mango fruit (*Mangifera indica L*) is one of the most popular fruits produced in tropical region of the world (Jasim *et al*, 2005). The world mango production showed an increasing trend averaging to 22 million metric tons per year. In 1999, total world production of mango reached 23,8 million metric tons ,which is 1.2 million metric tons higher than the 1995 production. (FAO, 1999). Worldwide production is heavily concentrated in Asia, accounting for 77% followed by South and Northern America with 13% share, Africa with 9% and Oceana at 1% (Sauco, 2004).

In 2005, world production of mango was estimated at 28.51 million metric tons. Between 1996 and 2005, production grew at an average annual rate of 2.6%. India is the largest producer of mangoes, accounting for 38.6% of world production from 2003 to 2005. During that period, India's mango crop average 10.79 million metric tons, followed by China and Thailand at 3.61 million metric tons (12.9%) and 1.73 million metric tons (6.2%), respectfully. Other leading mango producers are: Mexico, Indonesia, Pakistan, Brazil, Philippines, Nigeria and Egypt. Although currently only 3% of the world production of mango is traded globally, this represents a noticeable increase over the quantities traded 20 years ago (FAO, 2007).

2.1.3 History and current distribution of mango in Africa

Mango trees were reported in Somalia as early as 1331 (Griesbach, 2003). Ivory and slave traders brought seeds to Kenya as early as the fourteenth century and even today Kenya export mature mangoes to France and Germany and mature and immature mangoes to the United Kingdom , the latter for chutney- making (Anonymous ,2008).

Egypt produces 110,000 ton of mangoes annually and exports reasonable amounts to 20 countries in the near East and Europe. Mango culture in Sudan

occupies about 10,000 ha producing a total of 60,000 tons per/year (Anonymous, 2008). There is no documentation of the introduction of mangoes in to South Africa. However, a plantation was established in Kwazulu-Natal in 1860. Today the South Africa market, in all probability, has a achieved about 60,000 tons annually and fresh mangoes are exported to Europe (Human, 2008)

2.1.4 Mango in Sudan

Abusin and Hamed, (1971) and Saeed and Khattab, (1974) reported that 50% of the newly established fruit orchards in the Northern State, Khartoum and Blue Nile were planted with mango. About 2,832.80 hectares are grown in the Northern State, Khartoum State, Gezera State, River Nile State, Darfur State and Blue Nile State under irrigation and more than this grown under rain in Southern State, Nubba Mountains and South of Blue Nile State. In Sudan mango production in 1999 was 190 thousand tons (FAO, 1999). The annual production of mango in Sudan in (2004) was 603.00 (mmt) according to (AO A D, 2005). Mohamed, (1999) reported that the production of mango in Sudan has expanded tremendously because of the opened channels to European and Arab market. In Sudan mango is considered as an essential horticultural crop, with about 57 varieties and around 0.4 million tones annual production (UNEP, 2005).

Abbas, (2001) reported that Sudanese mango varieties are more than 30 cultivars. ‘’Baladi’’ varieties are more produced and there about 3 million trees of them in Abu-Gebeha and Rashad area in southern Kordofan State. The varieties that cover almost of production areas are Alphonse, Abu-Samaka and Galbeltowr, Mabroka Shendi and White Zibda. In other regions of Sudan mango cultivars are classified into four groups; namely, seed propagated, monoembryonic, polyembryonic and newly introduced cultivars. The seed propagated cultivars are characterized by variations in colors and shapes. The most important seed propagated cultivar is Kitchener (early – maturing cultivar – called Baladi) which represents 90% of the total production in Sudan.

(Sidahmed, 1993). Altoum, (2009) report that in Sudan mango cultivars are classified in to three groups: True Indian cultivars, Egyptian seedling cultivars of Indian origin such as Zibda, Alphonse, Malgoba and Hindibesinara and Sudanese seedling cultivars of Indian origin of high quality including Shendi, Timor, Nailm, Mabroka, Debsha and the famous sort Abu-Samaka.

Mangoes are grown all over the Sudan and are leading the Sudanese horticultural export. Many cultivars of excellent fruit quality are currently grown such as Abu-Samaka, Alphonse, Dibsha, Zibda, Galbeltowr and Shendi. However the majority of the mango fruit crop in Sudan is harvested from seedling trees, of which the local cultivar (Kitchener) is leading. Although the quality of fruit of these seedling trees is fairly good, they are usually too fibrous and not suitable for export especially to European markets (Elkashif *et al*, 2003).

The buildup of mango export industry in Sudan is dependent on mass propagation and planting of superior cultivars which are acceptable to all international markets. The only vegetative method of mango propagation currently employed in Sudan is approach grafting (Sidahmed, 1993). It is tedious, slow, and expensive and requires parent trees with low branches because the scion must be attached to the parent tree till the healing graft scion. Therefore, there is an urgent need to develop a quick and easy method of mango propagation where the scions are detached from the parent tree.

2.2 Importance of mango worldwide

2.2.1 Economical importance

The world's total mango production has increased over the years, from about 24.4MT in 1999 (FAO, 2000) to 33.8MT in 2008 (FAO, 2009). The major producers are Asia with about 74% followed by Latin America and the Caribbean with 16%, Africa with 10% and less than 1% for Europe and Oceania (Sauco, 2004; FAO, 2009).

Importation of processed mango such as canned mangoes, mango flavored beverages and processed mango pulp has also increased in the Last few years (de Almeida *et al*; 2000). The major importers are France, Great Britain, Netherlands, Germany, Belgium, Italy, Denmark and United States of America (Pimentel et al., 2000; Human, 2008)., while Mexico, Philippines, Pakistan, India, Thailand and South Africa are the major mango exporting countries .

In 1998 the total value of mango exportation was about US$ 375.5 million and the total exported volume was 510 thousand ton. This implies that only a small quantity of production was exported and consequently there is a possibility to increase the export market. The main characteristics of international mango markets are that the price is established at the import market. The consumer profit is also an important variable that determines mango demand and it is important that consumers are given information about alternative forms of consumption (de Almeida *et al*., 2000).

2.2.2 Nutritional value

Mango fruit contains a large fraction of the human's daily needed essential minerals and vitamins. The calorific value of mango is generally derived from the sugars and is high as that of grapes and even higher than that of apples, pears or peaches. The protein content is usually a little higher than that of other fruits,

except avocado. Mangoes are also a good source of thiamine and niacin and contain some calcium and iron as (Griesbach, 2003).

Mango fruit contains amino acids, fatty acid, organic acid, protein, minerals and vitamins. During the ripening process, the fruit are initially acidic, a stringent and rich in vitamin C. Ripe mango contains moderate level of vitamin C, but fairly rich in pro – vitamin A and vitamin B1 and B2. The edible portion takes up to 60-75 percent of fruit weight, raw mango consist of about 81.7% water, 17% carbohydrate, 0.5% protein, 0.3% fat and 0.5% ash. A 100g serving of raw mango has 65 calories (Mukherjee, 1997).

The mango nutritional value shows that it is an excellent source of copper and potassium mangoes also contain traces of magnesium, manganese, selenium, calcium, iron and phosphorus. Mangoes contain no cholesterol or saturated fats; fruit acidity is primarily due to the malic and citric acid. Acidity is cultivar – related; Florida cultivars have low acidity (0.5 – 1.0%) in comparison with Alphonso (3%). Following fruit set, starch accumulates in meso-carp. Free sugars including glucose, fructose and sucrose generally increase during ripening; however the sucrose content of ripe fruit increase three to four fold due to hydrolysis of starch (Mukherjee, 1997).

Fresh mangoes are processed and preserved into a wide range of products including pulps, juices, frozen slices, dried slices, pulp (fruit leather), chutneys, jam, pickles, canned in syrup, and sliced in brine (Bally *et al*.,2009).

2.2.3Medicinal and other uses

Mango is renowned for combating nutritional disorders (Griesbach, 2003). Each part of the plant has a number of functions: the fruit can heal many diseases such as beriberi, bronchial disease, kidney stone, insomnia, brain fatigue, mental depression and heart burn. It is a good laxative, depurative, digestive and diuretic and is advised for nervous people (Arcos, 1999). Unripe fruit can be

used against exhaustion and heat stroke and a half ripe fruit mixed with salt and honey is indicated to cure gastro-intestinal disorders. The leave can be prepared as an infusion and help for tooth ache. Weak teeth throat infection and elimate pyorrheao. A bark infusion can be a remedy for mouth infection in children (Bally, 2006).

Research results indicated that dietary fiber may help prevent certain types of cancer and can reduce blood cholesterol levels and that on medium mango fruit can contain up to 40% of the daily fiber requirements (Griesbach, 2003).

In addition to mangoes food value, it has also been used for medicinal values, in Samoa, a brake in fusion has been a traditional remedy for mouth infection in children, and also mango stone are useful as a substitute for maize in finishing broiler diets. The kernel is also used for medicinal purposes in moderation of anti-bacterial and anti-fungal activities (Jekayinfa and Durowoju, 2005).

2.3 Mango propagation

Cleft grafting is generally used with rootstocks of large diameters and normally more than one scion is inserted. However, a modification has been recently made where younger rootstocks and one scion can be used for large scale mango propagation (Kanwar and Bhajwa 1974; Azouz *et al*. 1984; Bajpaj et *al.* 1989; Nunez et al. 1996). It has been reported that cleft grafting is easier to use (Kulwal and Tayde, 1989) and more successful than other methods of grafting (Amin, 1978; Panickar and Deasi, 1989; Ram, 1997). Grafting methods in which the mango scion is detached from the parent tree include crown grafting, budding and cleft grafting (Hartmann and Kester 1983; Ram, 1993; 1997; Sidahmed, 1992; Reddy and Melanta, 1988). The success of grafting methods depends on season, age of both rootstock and scion and cultivar (Ram and Sirohi, 1989).

Monoembryonic mango varieties have single embryos of hybrid origin and do not produce true-to-type from seeds; Polyembryonic mango varieties produce two or more plant of nucellared (maternal) origin from each seed; they are predominantly true to type. Grafted mango trees usually produce fruits in 3 to 5 years in dry areas, while seedling trees usually take at least five years to come into bearing. Inarching is sometimes done to propagate mango varieties, and older trees may be top worked. Mangoes are not propagated from cutting or by air layering because the resulting trees are weak rooted (Basu, 1972).

2.4 Mango cultivars

Of more than 1000 known cultivars of mango, only 350 are of commercial importance. The original wild mangoes had small fruits with little, fibrous flesh and it is believed that natural hybridization occurred between *M. indica* and *M. syvatica* in South Asia. Selection for better quality has been carried out for 4000 – 6000 years and vegetative propagation for 400 years (Morton 1987). There are three main groups of mango cultivars: a) Most improved tropical cultivars with fibreless fruit and no turpentine flavor; b) Improved subtropical cultivars, with attractive, good quality fruit, but with unsatisfactory yield and less resistance to disease and c) Unimproved cultivars with high fiber content, external green color, turpentine flavor and poor shelf life, e.g. “Peach” and “Sabre” (Human, 2008).

Mangifera indica is believed to have first appeared during the Quaternary period (Mukherjee, 1951). Blume (1885) considered that mango might have originated from several related species, primarily located in Malay Archipelago. On the basis of ancient accounts the travelers and written historical record it was believed for many years that mango must originated in India and spread outward from there to South east Asia and hence to the new world and Africa (Mukherjee 1997).

Mango can be classified in to three groups: namely; Indian cultivars, Philippine and Indo-Chinese types and Florida-originated selections or cultivars. The Indian cultivars are mainly monnoembryonic; typically of somewhat "turpentine" character highly colored (mixes of reds, purples and yellows), and susceptible to anthracnose disease. The Philippine and Indochinese types, are largely polyembryonic, not highly colored (green to light green to yellow), non-turpentine, fibreless, fairly resistant to anthracnose disease. The Florida-originated selections or cultivars, of which many have risen and declined over the decades. The present-day leaders for commercial production and shipping are Tommy Atkins, Keitt, Kent, Van Dyke, Jubilee and Haden. Tommy Atkins and Keitt cultivars represent 50% of the commercial crop. (Morton, 1987, Crane, *et al* 1997).

Today, the Subtropical Horticulture Research Unit (SHRU) of the U.S. Department of Agriculture and the Agricultural research and Education Centre of the University of Florida, together maintain 125 mango cultivars as a resource for mango growers and breeders in many countries (Morton, 1987). Singh (2005) reported that the commercial varieties of mango, although having a wide range of adaptability, are specific to different regions of the country.

There are more than a thousand horticultural varieties of mango in India alone. In horticulture a variety is generally defined as a group of individuals propagated a sexually from single parent. Varieties which actually originated from seedlings have been multiplied by grafting and other means of vegetative propagation. All the choice varieties of today have therefore come out of deliberate natural selection (Nair, 1994). Singh and Sturrock, (1969) reported that most cultivars arose from chance seedlings. Breeding work is difficult because of low success rates in pollination, along life cycle, and other problem. Certain cultivars are self-incompatible (Samson, 1986).

Human and Snyman (1998) stated that, important commercial characteristic, of cultivars include time of ripening, internal quality, external appearance, fruit size, resistance to bacterial black spot and other disease, tree size and consistent high yields.

In Sudan there are more than 30 traditional mango cultivars in addition of hundred seedling cultivars. Most mangoes grown in Sudan are monoembryonic cultivars such as Alphonso, Mulgoba, Mubroka, Desha, Shendi, Zebda, Jolik, Abu samaka and Nailum. Seedling cultivars grown in Sudan are Kitchener, Betbady, Sinaria, Shreefia, Hindi Abusinara, and Iwis. The new introduced cultivars cultivated in Sudan were imported from South Africa such as Tommy Atkins, Keitt, Kent, Sensation and Heidi.

In 1942 thrower introduced 38 mango cultivars from Egypt and grown them in Shendi nursery as first germplasm collection.

2.5 Mango characterization and evaluation

2.5.1 Morphological characterization

The application of morphological markers is the simplest of the formal, standardized and repeatable method of evaluating crop genetic diversity. Some of the most important advantage of using morphological characterization are that published descriptor lists are readily obtainable for most major crop species, it can be carried out in situ, is relatively low- cost and easy to perform. Morphological characterization is the first step that should be done before more profound biochemical or molecular studies are carried out (Hoogendijk and Williams, 2001).

Various studies with different tropical trees have utilized morphological characterization, including *M. indica*. Differentiation between cooking and dessert bananas was done based on morphological, physical and chemical characteristics of 23 unripe cultivated varieties of Colombian Musaceae (Gibert

et al., 2009). A lot of experiments and evaluation have been held to study the morphological characterization of the different genotypes and cultivars. The mango is a rather unique fruit in that there is such a wide variation in sensory characteristics (include color, appearance, aroma, flavor and texture), depending on cultivar. Consumer preferences for color, size and shape may vary from region to region. Appearance is the first impression the consumer gets from the fruit. About twenty years ago, a study was conducted by Mattern and Pennock, (1971) in supermarkets in Puerto Rico to determine the market potential for improved varieties. They concluded that Puerto Rican consumers showed a strong preference for semi- ripe mangoes and that coloration and fruit size was very important determinants of acceptance. Color was more important than size. Knight, (1985), in Florida, in describing criteria for evaluating fruit characters in mango, stated that the North American preference is for a bright, highly- color fruit with a red or purple blush.

This is apparently also the case in Hawaii. The same is probably not the case for consumer preferences in Asia and Southeast Asia, where different varieties are grown. The flavor characteristics of mango include the aroma components; in a study by Gholap et al. (1971).The main objective of variety characterization is to obtain a better understanding of the principal characteristics of the different parts of the plant. Successful mango varieties are chosen for essential agronomic trail such as taste, color and weight, shape of the fruits as well as tree height, leaves and inflorescences rather than yield (Chadra and Pal, 1986).

2.5.1.1 Mango tree

Mango trees have different types of canopies, according to the propagation type, density type of variety and eco-geographical conditions. Some varieties, such as “Latra” are considered to have a creeper-growth habit because of its spreading nature. The biggest mango tree in the world is found in India and has a spreading crown of 36.6 - 45.7 m (Singh, 1968). The size of mango tree varies

greatly depending on condition in which it is grown. It can be trained to grow as small tree or it can be a giant tree. Under ideal soil conditions and with age the tree can attain a height of 10 – 40m depending on the variety planted (Budwar, 2002).

When trees are propagated by seed they develop a sympodially branched appearance according to the Scarron's model, while grafted trees tend to be a shorter. The tree height can reach 8 – 35m, depending on cultivar, climate, soil type and rootstock (Human, 2008).

Mango tree, grown from seeds are known as "seedlings" have long straight stem tree are sympodially branched. Grafted tree on the other hand are dwarf with spreading branches. Seedling tree live much more than 100 years, whereas grafted ones live only 80 years or less (Singh, 1960). Mukherjee, (1997) mentioned that, the mango tree can survive for more than 100 years. Morton, (1987) reported that, the mango tree is long lived, some specimens being known to be 300 years old and still fruiting.

2.5.1.2 Leaf

There are great variation in leaf length, width and petiole length between different cultivars, and even within the same cultivar according to the season of growth and position of the leaf on the flush. Usually lower leaves of the flush are longer than the upper ones, the middle leaves, have the longest petioles. Mango leaves are evergreen, alternate, borne mainly in rosettes as the tips of branches and numerous twigs from, which they droop like ribbons on slender petioles (Morton, 1987).

Characteristic leaf shapes include entire, leathery, short, pointed and oblong to lanceolate leaves. The length is about 450mm. Differences are due to varietal variation, climate, cultural practices and growth stages. Young leaves from different varieties can present different colors. This can vary from copper- red to

purplish in color. At maturity the leaf color changes to dark green and usually smells like turpentine (Fivaz, 2008).

2.5.1.3Inflorescence and flowers

The mango in florescence is primarily terminal on a panicle (Bally, 2006). Singh (1968) found that the inflorescence is most commonly pubes cent, although at times it is glabrous. Inflorescence color ranges from yellow to light green with crimson patches or with crimson flushes on branches. The number of panicles per plant ranges from 600 – 6000 and the number of flowers open between 9 – 11am and the receptivity of the stigma occur about 72h after an thesis (Genu and Pinto, 2002). Samson (1986) reported that the inflorescence is a widely branched panicle, 10 – 60 cm long with thousand or more male and hermaphrodite flowers – Morton(1987) mentioned that 3000 – 4000 small flowers, yellowish or reddish flowers, 25% to 98% male, the rest hermaphroditic, are borne in profuse, showy, erect, pyramidal branched clusters 6 – 40 cm high. The greenish-white or pinkish flowers are borne in inflorescence usually located on current or previous year's growth. Male flower usually outnumber the bisexual or perfect flowers (Griesbach, 2003). The hermaphroditic flowers have a shiny, green, globous, superior ovary with an anatropic ovule and a style with a single lobe.

The male and hermaphroditic flowers normally appear on the apical end of the inflorescence and are long pedicel late. The calyx and corolla have five pubescence sepals and five white, pink or purplish petals, followed by five yellowish nectar glands, a single fertile stamen and a number of non-fertile stamens of different sizes, known as staminodes (Fivaz, 2008).

2.5.1.4 Fruit

Mango fruit of the different cultivars varies in shape, size, appearance and internal characteristics. The fruit have great variations in the form, size, shape,

weigh, flesh and skin color and quality. The fruit are nearly round, oval, ovoid-oblong, or somewhat kidney-shaped, often with a break at the apex, and are usually more or less lop-sided. Fruit was found to be range from 6.25 to 25cm in length (Morton, 1987). (Samson, 1986) the fruit weight ranged from 100g to 2 kg.

The fruit grow at the end of a long string-like stem (the former panicle) with some times two or more fruits at stem. It is resinous and highly variable with respect to shape and size (Mukherjee, 1997). The skin is leathery, waxy, smooth, fairly thick, aromatic and ranges from light- or dark green to clear yellow, yellow-orange, yellow and reddish- pink or more or less blushed with bright or dark red or purple-red, with fine yellow, greenish or reddish dots, and thin or thick whitish, gray or purplish bloom, when fully ripe. Chlorophyll, carotene, and xanthophyll's are all present in the fruit, although chlorophyll disappears during ripening, whereas anthocyanin carotenoids increase with maturity (Lakshminarayana, 1980). Fruit color at maturity is genotypes dependent. The meso-carp can be fibrous or fiber free with flavor ranging from turpentine to sweet (Mukherjee, 1997).

The fruit is a fleshly drupe, varying in size from 2.5 – 30 cm long, may be kidney –shaped, ovate or round and weight of approximately 200g to over 2000g. The leathery skin is waxy and smooth and when ripe entirely pale green or yellow marked with red, depending on the cultivars (Griesbach, 2003).

2.5.1.5 Seed

Mango seed are recalcitrant and cannot survive for more than few days or weeks in storage at ambient temperatures. This important characteristic of mango seeds would have prevented their long dispersal until recent time. There is a single, longitudinally ribbed, pale yellowish- white, woody stone, flattened, oval or kidney- shaped, sometimes rather elongated. Stone has a long one side a bread of short or fibers clinging to the flesh cavity, or it may be nearly fibreless. Within the stone is the starchy seed, either monoembryonic or polyembryonic. (Morton, 1987).

2.5.2 Molecular characterization

2.5.2.1 Molecular markers

In recent years, different molecular systems such as restriction fragment length polymorphism (RFLP), Random Amplified Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), and Simple Sequence Repeat (SSR) have been developed and applied to a range of crop species including cereals (Gurta *et at*, 1999). Molecular markers provide a way to measure true genetic variability in the absence of environmental influences (Antunnes *et al*., 1997). However, markers must be heritable, discriminate between accessions, easy and cost-effective to measure and evaluate, and provide reliable repeatable results (Hills and Moritz, 1990, Twanda, 2004). Molecular markers are used in molecular biology and biotechnology experiments where they used to identify a particular sequence of DNA. As the DNA sequences are very highly specific, they can be identified with the help of the known molecular markers which can find out a particular sequence of DNA

from unknown groups. The term DNA-fingerprinting was in traduced for the first time by Alec Jeffrey in 1985 to describe bar-code-like DNA fragment patterns generated by multilocus probes after electrophoresis separation of genomic DNA fragments. The emerging patterns make up a unique feature of the analysed individual and are currently considered to be the ultimate tool for biological individualization. Recently, the term DNA fingerprinting is used to describe the combined use of several single locus detection systems and is being used as versatile tools for investigating various aspects of plant genomes. These include characterization of genetic variability, genome fingerprinting, genome mapping, gene localization, and analysis of genome evolution, population genetic, taxonomy, plant breeding, and diagnosis (Swati *et al*, 2008).

Molecular markers have the advantages of being abundant, phenotypically neutral, show absence of epistasis and are not influenced by the development stage or tissue of the plant or environmental conditions (Mohapatra, 2007).

Many molecular markers are now a days utilized for numerous purpose, eig., characterization of germplasm, varietal identification and clonal fidelity testing, assessment of genetic diversity, validation of genetic relationships and marker-assisted selection (Hoogendij and Williams,2001). Different classes of DNA markers, each with its own advantages and disadvantages, are available.

The main features of the molecular markers may be outlined as follows:-

2.5.2.1.1 Restriction Fragment Length Polymorphism (RFLP)

RFLP use restriction enzymes that cut the DNA molecule at specific sites, called restriction sites, resulting in different fragments of variable lengths. After separation by electrophoresis, fragments transferred to nitrocellulose or nylon

filters through southern blotting followed by hybridization with radioactively labeled DNA probes and visualization using photographic film (Varshney *et al.*, 2004). Single- locus RFLP markers have been used as a diagnostic tool for screening agronomical valuable traits (Kretschmer *et al.*, 1997; Jefferies *et al.*, 1999).

2.5.2.1.2 Amplification Fragment Length Polymorphism (AFLP)

AFLP technique has been used to identify markers linked to disease resistance loci (Vos *et al*., 1995). AFLP analysis was demonstrated to be useful for identification of mango cultivars and root stocks (Kaskkush *et al.*, 2001). The authors reported genetic relationships and diversity with. In mangifera species, with no differences between morphological and molecular in this study. Hence AFLP analysis can be considered an applicable and effective tool in taxonomic analysis (Phumichai *et al.*, 2000).

2.5.2.1.3 Simple Sequence Repeats (SSR)

According to Holton (2001), microsatellites or SSRs are simple sequence repeats of about 1-6 nucleotides. The advantages are that they are dispersed and plentiful in all genomes, with elevated levels of polymorphism compared to other molecular markers. As a disadvantage SSR analysis is an expensive and time-consuming process mainly when the creation of a library is needed. For many crops, to construct a high resolution linkage map, using only SSR markers is expensive, but it is usually more reasonable to combine SSR and AFLP analysis. Other advantages of SSR include co-dominant inheritance, analytical simplicity and its transferability (Weber, 1990; He *et al*., 2003).

SSR is the acronym for single sequence repeat or microsatellite (Olufowote *et al*., 1997). Microsatellite is powerful for identification of within cultivar variation. The major advantages of microsatellites are their ease of use, low cost of analysis, and ability to detect genetic difference even among closely related

individuals. The first tow advantages are critical for the wide-spread use of DNA markers in large scale breeding programmes. The third advantage is of paramount importance in modern plant breeding programmes. Thus, microsatellite DNA markers offer the promise of DNA markers-assisted selection (MAS).

2.5.2.1.4 Random Amplified Polymorphic DNA (RAPD)

RAPD is a molecular marker technology, first developed by Williams *et al.*, (1990), utilizes PCR (polymerase chain reaction) method to amplify several loci within genome with a single random sequence oligonucleotide primer. RAPD and related DNA amplification fingerprinting methods are increasingly used for taxonomic identification, linkage analysis and QTL studies (Tuinstra, italic 1998). RAPD analysis have the advantage of being neutrally selective, do not use radio-isotopes, can use DNA of low quality and primers are more accessible than that of the RFLP technique. However, disadvantages include a limited detection of polymorphism, alow resolution profile that may resulted in low bands and detection of only the dominating allomorphs. It was found that RAPD, due to low annealing temperatures, are less reproducible than other techniques (Williams *et al.,* 1990; Kapteyn and Simon, 2002).

2.5.2.1.5 DNA extraction

DNA can be isolated from cells of plants, animals or micro-organisms and can be fragmented into groups of one or more genes (Smith and Smith, 1992). DNA extraction is difficult, especially from plants, because of problems due to the presence of DNA as activity which degrades DNA and the presence of macromolecules which polymerize to the DNA during the isolation procedure (ICARDA, 2003). So, high levels of secondary metabolites and polysaccharides and polyphenols including flavonoid compounds represent a significant barrier to the extraction of pure genomic DNA (Daneshwar and Kannen, 2005).

Many standard methods are available for isolation plant genomic DNA. The nuclease problem is reduced by removing cations such as Mg++ which are required for nuclease activity. The reagent acetyl methyl ammonium bromide (CTAB), which is used in several procedures, binds strongly to DNA displacing proteins and preventing degradation of DNA (Sharma *et al.*, 2002).

2.5.2.1.6 Polymerase Chain Reaction (PCR)

The PCR technique is used in various experiments and procedures in molecular biology, plant breeding, evolutionary biology, genetic engineering, and population genetics (Smith et al. 1996). It was developed in 1983 by Kary Mullis and is used to make numerous copies of specific genetic material. The replication of the genetic material is carried out by enzymes called DNA polymerases (Gerrit *et al.,* 2005). These enzymes initiate the synthesis of DNA starting from a primer bound to a template. The primers are generally 9 to 20 bases in length and establish the site where DNA replication begins. With the PCR, any particular stretch of genetic material can be replicated several times simply by selecting a pair of primers that flank the desired stretch of DNA.

The PCR involves three temperature incubation or steps that are repeated. In the first step of the reaction, called denaturation, the two strands of the target DNA are separated by heating the DNA to 94°C. In the second step, called annealing, two primers hybridize to complementary sequences in the single strands. During the third step, called extension, the primers are extended by thermos table DNA polymerases (isolated from the bacterium *Thermus aquaticus*) at 72°C.

2.5.2.1.7 Molecular markers for genetic variation in mango

Forty genotypes from the Brazilian Research Institute (EMBRAPD) were analyses using 13 primers that produced 176 reproducible RAPD markers. Of the 176 markers, 116 were polymorphic, detecting 65.9% polymorphism. The authors concluded that RAPD analysis showed efficient differences to determine genotype polymorphism in mango (de Sousa and Costa Lima, 2004).

Embrapa Cerrados has been working on mango breeding program through intervarietal hybridization using cultivars from India, South Africa, Nigeria, Mexico, USA and Brazil since 1983. The objective of this work was to evaluate the genetic variability of 28 mango cultivars of the parental group used in the *Embrapa Cerrados* breeding program. The genomic DNA of each cultivar was extracted and amplified using 21 primers to obtain RAPD molecular markers. These markers were transformed into a binary matrix data to estimate genetic distances among cultivars and to perform cluster analysis. From the 350 molecular markers obtained, 16.3% were monomorphic. The genetic distances among the 28 cultivars ranged from 0.098 and 0.331. The lowest genetic distances were detected between the cultivars 'Edward' and 'Glenn' (0.098), 'Tommy Atkins' and 'Keitt' (0.101), as well as 'Apple' and 'Malindi' (0.112). There is high genetic variability among mango cultivars from different countries, including the Brazilian ones. There was a grouping tendency of the important cultivars from USA. These results emphasize the importance of the cultivars used in the *Embrapa Cerrados* breeding program and provide useful information for future mango breeding activities (Faleiro, 2010).

In the genetic variability among 20 *Mangifera indica L.* cultivars from Sudan were investigated using 10 RAPD primers, which were found to be polymorphic with the mango cultivars investigated. Out of 76 bands, 69 bands (90.78%) were found to be polymorphic. The genetic coefficient among the cultivars ranged from 6% to 40% (Elgozuli, 201).

A study done on genetic diversity and relationship among 112 mango plants from different state in Mexico using AFLPs, indicated high genetic similarity with heterozygosis values ranging from 0.38-0.68, and the amplified products were 308 with 87.3% polymorphism (Galvez-Lopez, *et al.*, 2009).

Genetic variation and relationship among 28 mango germplasm were analyzed using RAPD. Out of 20 primers screened, four were selected, which gave 50 clear and bright fragments, out of which 48 fragments were polymorphic. The proportion of polymorphic loci and gene diversity value across all loci were 96% and 0.29, respectively (Rahman *et al.*, 2010).

Yamanaka, italic. (2006) reported on a study using AFLP to analyses 35 mango accessions using eight primer combinations that produced a total of 518 fragments and 96.3% of them (499) were polymorphic.

DNA fingerprint information was used for identification of 20 mango cultivars for genetic relatedness of mango cultivars and for genetic analysis a family structure. Genomic DNA was extracted from young leaves, resulting in well-resolved bands representing highly polymorphic loci. Specific patterns were obtained for each cultivar. Based on DNA fingerprint information, genetic distances between 20 mango cultivars were evaluated and an evolutionary tree was established (Lavi *et. al*., 2005).

Genetic diversity of 25 mango genotypes from the same species *M. indica* was assessed using RAPDs and 45 primers (Rajwana, italic 2008).

DNA analysis was carried out in 29 Indian mango cultivars comprising popular.landraces and some advanced cultivars. PCR amplification with 24 primers generated 314 bands, 91.4% of which were polymorphic. Jaccard's similarity between pairs of cultivars ranged between 0.318 and 0.75 with a mean of 0.565. (Karihaloo, *et. al.,* 2003)

2.6 Pests and Diseases

Mango export come on top of Sudanese horticultural crops. It is characterized by continuity of production for almost 10 months of the year. However there is

an ever increasing demand for export, but many constrains are facing mango which led to decline the amount of the mango exported from almost 10 thousand tons in 1998 to one thousand tons in 2006 (Annual Report, Ministry of Agric.) The main constrains include the damages of fruit flies and spongy tissue, which led to decline of quality of the Sudanese mango fruits and hence the export capability.

2.6.1 Fruit flies

Fruit flies belong to the genera *Anastrepha* (eight species), *Bactrocera* (30 species), *Ceratitis* (seven species), Dirioxa (two species) and *Toxotrypana* (one species). *Bactrocera* species are pests of major importance, especially in the eastern hemisphere. The female fruit flies belonging to this species introduce their eggs underneath the skin of the ripe fruit and after hatching, the larvae burrow deeper in to the fruit. They contaminate the fruit withfrass and provide access for fungi and bacteria that can cause secondary infections. Fully grown larvae drop to the ground and enter the soil where they pupate. Humid weather is considered to be favorable for *Bactrocera* fruit flies and Bactrocera population decrease during dry periods. Chemical control involves Malathion for three months (Pena and Mohyuddin, 1997).

The genus *Ceratitis* belong to the family Dacinae, tribe ceratitini, and sub tribe ceratitina, while the genera Dacus and Bactrocera belong to sub family Dacinae, tribe Dacini (Drew, 1989). In Sudan fruit flies were reported at Khartoum State by Venkatraman and Elkhidir in 1965. Ali (1967) found fruit flies in the Northern region (Shendi, Hdeba), Khartoum, Kassala and the Southern region (Yambio, Meridi, Yei, and Juba). Among the fruit flies found in the Sudan, Ceratitis capitata and Ceratitis cosyra are considered as devastating pests to the mango fruits all over the country especially at Shendi, Senga, and Sennar areas (Ahmed, 2001). In addition, a new species of the genus *Bactrocera* was reported from Blue Nile areas known as *Bactrocera invadens* (Drew, 2005) which

constitute a threat to fruit production and fruit exportation in the Sudan. The population abundance of the fruit flies generally increase with the rainy season, high population was recorded during the humid months of July and August, while low population were recorded during March (Abedel Magid 2010). In the River Nile State the damage percentage reported was 85-90% on mango (Gubara and Abu Elgasim, 2004). In the year 2007, the fruit flies problem became so severe to the extent that they were upgraded and added to the list of the notorious national pests of Sudan.

In North and South Kordofan states, *C. cosyra* was the more commonly occurring species on fruit trees followed by *B. invadens* (Bashir, 2007 ; Ali, 2007). Also in the River Nile State, *C. cosyra* was dominant on mango followed by *B. invadens* (Abdellah, 2007). Also, *C. cosyra* was detected in all months with relatively high populations from the last week of February to the last week of March (Mohamed and Ali, 2008). An earlier study in the Gezira state showed that *C. cosyra* was the predominant species of fruit flies on mango (Ahmed, 2001). General surveys in different state of Sudan showed that *Ceratitis cosyra* (Walker) commonly known as the mango fruit fly has already become a cause for concern in Kassala, the Blue Nile and khartoum states.

2.6.2 Spongy tissues

In spite of the economic importance and increasing demand, the spread of mango cultivation, is handicapped by certain problem, among which the development of spongy tissues in its fruits has received general attention of the scientists for the last 20 years. The spongy tissues, a ripening disorder, are often described as soft Centre, white corky tissue or internal breakdown in mango fruit. The peculiarity of this malady is that the external symptoms of spongy tissue affected fruits are not apparent either at the time of picking or at the ripe

stage. The affected tissue is visible only when the ripe fruit is cut in to two halves.

The peculiarity of this disorder is that the external symptoms of spongy tissue in affected fruits are not apparent either at the time of picking or at the ripping stage. The affected tissue is visible only when the ripe fruit is cut in to two halves. As a result of this disorder, the quality of affected fruit is impaired. It renders the fruit unfit for human consumption and fetches low value in the market hence; it has become a problem in expansion of mango cultivation (Rane italic, 1976).

2.6.2.1 Biochemical nature of spongy tissue

Studies during 1977- 1978 by Katrodia italic, (1978) revealed that, in comparison to normal healthy ripe pulp of Alphonso fruit, the biochemical constituents like acidity and starch increased, while pH, ascorbic acid, beta carotene, reducing as well as non- reducing sugars, enzyme activities of amylase and invertase were deceased in spongy tissues. Similar trend was observed with sun desiccated tissues also. The unaffected pulps around spongy tissues as well as around sun- desiccated tissues showed more or less similar trend as that of healthy pulp. These similarities in both the types of tissue probably indicate spongy tissue is formed because of the heat which is emitted by soil as convective flux. Thus, spongy tissue in Alphonso fruit of mango seems to be a physiological disorder in which fruit pulp remains unripe because of unhydrolyzed starch due to physiological and biological disturbances caused by heat in the pulp of a mature fruit at pre- and post- harvest stage.

Chapter 3

MATERIALS AND METHODS

3.1 Sampling area

Shendi is located on the east bank of the River Nile, River Nile state it is north-east of Khartoum about 170 Km, between latitudes (16 -42) north and longitude (33-26) east, it is the main area of mango cultivation in Sudan. Many cultivars have been grown in this area.

3.2 Sampling materials

Thirty mango (Mangifera indica L) trees were used in this study. Sixteen of which were grafted genotypes of Indian or Egyptian origin of known varieties .V.Z: Abu samaka ,Shendi, Nailum, Mitlaky, Mabroka, Zibda, alphonse, Galbeltowr, Malgoba, Julik, Timor, Dibsha, Mahmoudi, Walibasha, Bet Abusamaka, Segrest (1 – 16).These varieties were well known in Sudan and cultivated for many years by farmers.

Recently three cultivars were introduced from South Africa these were, Elkent, Elkeitt, and Tommy atkinz(17 – 19). Eleven varieties were grown directly from seeds (Balady). Which in clude :Kutchineer, Betbady , Wadsrear, Sinaria, Shabala , Shreefia, Yageen, Bizrtshendi, Rasmaktoul, Taiba, Higazia (20 – 30) These cultivars showed high production with high quality fruits.

3.3 Morphological characterization

Morphological characterization of the selected cultivars was carried-out for leaves, inflorescences, fruits and seeds using Diversity International Descriptor (IPGRI, 2006).

3.3.1 Samples collection

From each variety three trees were used for collecting the leaves and inflorescences, and from each tree three leaves or inflorescences were taken for study randomly.

3.3.2 Leaf characterization

Leaves were cut by apex from the base of the leaves and were taken to the laboratory for measurement.

3.3.2.1 Leaf length

The length of each leave was measured from the apex to the base in cm.

3.3.2.2 Leaf width

The width of the leaves was measured of the widest area of the leaf in cm.

3.3.2.3 Petiole length

The length of the petiole was measured from the base leaf to stick branch in cm.

3.3.2.4 Leaf shape

Blade shape, apex shape, base shape, texture and margin were tested and compared

to the according to descriptor.

3.3.3 Inflorescences characterization

Inflorescences were cut by apex from the base of the inflorescences and were taken to the laboratory for measurement.

3.3.3.1 Inflorescences length

The length of the inflorescences was measured from the apex to the base in cm.

3.3.3.2 Inflorescences shape

Blade shape, density, color, and floral leaves were tested and compared to according to descriptor.

3.3.4 Fruit characterization

Mature mango fruit were collected from the selected cultivars. From each variety under test tree mango fruits were collected from each of the tree replicated.

3.3.4.1 Fruit shape

The fruit shape was determined. The apex and the beak type of each fruit were also determined. The shape of the fruit shoulder and the sinus of the fruits were also determined.

The fruits under test were weighted using the normal balance.

The length and width of the fruits were measured at the most longer and wider part of the fruit by the vernier. The circumference was measured using plastic meter. And the averages of readings were tabulated.

3.3.4.2 Skin of ripe fruit

The skin colors of the collected fruit samples were determined as in the pulp color, and the results were tabulated. The weight of the fruit skin was measured.

The skin of the fruit was removed by hand and washed many times to remove the adhering fibers.

The sample was transferred to the laboratory for measurement by sensitive balance.

Three fruit were used from each tree and three replicates were used for each variety.

3.3.5 Pulp characterization

The pulp color of the collected fruit sample was determined. The texture of the fruits was also determined. The pulp weight of each sample was measured as follows. The total weight of the fruit was measured in grams by normal balance. The seed of the fruit was washed genteelly and weighted.

The weight of the skin and the weight of the seed were subtracted from the total fruit weight.

The balance of this was determined as the pulp weight.

3.3.6 Fiber

3.3.6.1 Fiber weight

The weight of the fruit fiber was measured as follows:

A random area from the fruit fiber was splitted and weighted including the skin and pulp. The weight of the skin was measured and the pulp weight was determined.

The pulp was washed genteelly in Amish to separate the fibers from the rest of the pulp. Then the fibers were weighted.

The weight of the fibers in the fruit was calculated as follows:

$$\frac{\text{The weight of the total pulp X the fiber weight in the black}}{\text{Pulp weight in the black}}$$

3.3.6.2 Fiber weight content percentage

The fiber content percent of the fruit was calculated as follows:

$$\frac{\text{The fiber weight}}{\text{The pulp weight}} * 100$$

3.3.7 Seed characterization

From the fruit samples the seeds were washed 3-5 times to remove any fibers or pulp.

The weight of the seeds was measured using the normal sensitive balance in 3 replicated.

The seed length, width and the thickness was measured at the middle of the seed using the vernier as in the fruit measurement.

The pallem of venation and the veins of the seed were mentioned.

3.4 Molecular characterization of mango germplasm using DNA molecular markers:-

Molecular characterization of mango genotypes using the molecular marker Random Amplified Polymorphic DNA (RAPD) was conducted in the Biotechnology Laboratory, Department of Molecular Biology, Faculty of Sciences, University of Khartoum, Sudan.

3.4.1 Plant material:-

Three newly-emerged leaves were collected from the eleven seedling mango cultivars: Betbady, Kutchineer, Wadsrear, Higazia, Shabala, Bizrtshendi,

Sinaria, Taiba, Rasmaktoul, Yageen, and Shreefia (1 – 11). Samples were kept in paper bags. Then stored in the refrigerator (4°C) for further analysis.

3.4.2 Methods

3.4.2.1Genomic DNA extraction

Genomic DNA of each cultivar was isolated by a sap-extraction method (CIMMYT, 2005) from 100 mg of fresh leaf tissues. Leaves were cut into small pieces and put in a 15 ml Falcon tubes. 5 ml of extraction buffer (50 mM Tris–HCl, 25 mM EDTA, 1 M NaCl, 1% CTAB, 1 mM 1, 10-phenathroline, and 0.15% 2-mercaptoethanol) was added to the tubes and the contents were mixed in a blender. The mixture was incubated at 60°C for 1 h, and then mixed with equal volume of chloroform-isoamyl alcohol (24:1). After centrifuging at 12,000 rpm, the supernatant was transferred to a new tube and incubated with isopropanol for 30 minutes to precipitate the DNA in a pellet from. The pellet was dried and re-suspended in 200 ml of TE buffer (10 mM Tris–HCl, 0.1 mM EDTA, pH 8.0) .The DNA solution was mixed with 20 ml of 8 M ammonium acetate and 400 ml of cold absolute ethanol for 30 min, centrifuged for 10 min, and air- dried at room temperature. The DNA was then re-suspended in 300 ml of TE buffer and stored at -20°C till used.

3.4.2.2 Agarose gel electrophoresis of the extracted DNA:-

The extracted DNA was electrophoresed in 1.5% agarose gel [0.75g agarose dissolved in 50 ml of 1x TBE buffer (0.089 mol/L Tris-borate, and 0.002mM EDTA, pH 8.00)] (Sawada *et al*., 1995). Then 2 µl of ethidium bromide (10 mg/ml) were added prior to casting the gel, the comb was adjusted and the gel was poured (making sure that there were no bubbles). While the gel was solidifying, DNA mixtures were prepared for electrophoresis as follows: 1 µl of each DNA sample was transferred to a clean Eppendorf tube and 3µl of loading dye (bromo phenol blue dye) was added to the DNA sample. The content was

mixed several times using a micropipette. The comb was removed with gentle back and forth motion and the gel was then immersed in 1x TBE buffer. The buffer was added until it reached a level approximately 3-5 mm above the gel surface. The sample mixtures were loaded into the wells using plastic-tipped micropipettes. 1Kb ladder (Invitrogen) was used as a molecular weight marker. The apparatus (Habaib, U.K, 9H 310083) was closed and the power was turned on, the voltage was adjusted to 75V (400mA) and the running was continued without cooling for 20 minutes after which the gel was visualized under trans illumination cabinet (Model TM-10E, Uvitec. Product) and image was captured and photographed. Extracted DNA was then stored refrigerated until used as a template for PCR amplification.

3.4.2.3 Polymerase chain reaction

For genetic diversity studies four RAPD primers were used to amplify the genomic DNA. The primers were purchased from Gene link, Inc. and Operon Tech., NY 10532. These were OPC9, OPY14, OPR10 and OPL18(Table 1).

PCR amplification reactions were carried out in a total volume of 20 µl. Each PCR mixtures contained (Final conentration): 5X FIRE Pol PCR Master Mix (Ready to load), 5 X reaction buffer (0.4 M Tris-HCL,0.1 M (NH_4) SO_4, 0.1% W/V Tween 20), 12.5 Mm dNTPs, 50 ng of the primer under test, 1 U Taq polymerase and 20 ng template DNA.

The amplification program used consisted of one cycle at 94°C for 5min, followed by 35 cycles of initial denaturation at 94°C for 1min, annealing at 32°C for 3min, extension at 72°C for 2 min and a final extension step at 72°C for 10 min.

Table (1) DNA sequences and sources of arbitrary primers used in PCR- based RAPD

Primes	**Sequence**	**Oligonucleotide size**
OPC9	CTCACCGTCC	10 bases
OPL18	ACCACCCACC	10 bases
OPR10	CCATTCCCCA	10 bases
OPY14	GGTCGATCTG	10 bases

Chapter 4

RESULTS AND DISCUSSION

4.1 Morphological characteristics

4.1.1 Leaf characterization

4.1.1.1 Leaf length, width and petiole length

Table (2), (Fig.1) showed the length, width and petiole length of the leaves of mango cultivars under study. The cultivars showed a significant difference ($P \leq 0.05$) between them regarding the leaf length. Almost all the seedling cultivars showed longer leaves ($\geq$ 20 cm in length). Whereas South African cultivars have shorter ($\leq$ 20 cm) leaf length. On the other hand varying leaf length was reported for the grafted cultivars depending on the cultivar itself. Ras maktoul cultivar showed the longest leaf length (28 cm) followed by Bet bady Kutchineer and Taiba.

Grafting cultivars vary in leaf length raging between 15.467 and 24.333cm which are almost shorter than the seedling cultivars and longer than South African cultivars. Significant differences were shown between the seedling and grafted cultivars whereas no significant differences were observed between South African cultivars.

Leaf width showed significant differences ($P \leq 0.05$) between the cultivars. The width of the seedling cultivars showed the wider ones among the cultivars ranging between (3.700- 7.067 cm). No significant differences were observed between the grafted seedlings which showed the narrower ones.

Petiole length showed significant differences ($P \leq 0.05$) between the cultivars but not between the cultivars within one word in each group. The petiole showed varying length depending on the cultivar. There are great variations in leaf length, width and petiole among the cultivars. These findings coincide with previous findings by (Elgozuli, 2011) who reported leaf length of 15- 35cm,

width ranged from 4.0- 10.0cm, and petiole length of 1.1- 7.0cm. budwar (2002) reported similar ranges of length, width and petiole depending on cultivar, climate and cultural practices. Variations within the same cultivar were observed as a result of the area where the cultivar was grown, season of growth and position of the leaf on the flush (Abdelrahman, 2009).

4.1.1.2 Leaf blade, apex and base shape

The leaf blade shape, apex shape and base shape was shown in (table 3).

The leaf blade shapes of the cultivars vary between lanceolate and elliptic shape. Most of the seedling cultivars were lanceolate were as no dominant shape was observed with the grafted cultivars. Two of the South African cultivars showed lanceolate shape the third one showed elliptic shape (Fig.2)

Most of the cultivar showed acuminate apex shape with little variation to acute shape in few cultivars either seedling cultivars or grafted cultivars. The dominant apex shape of South African cultivars was the acute shape (Fig.3).

Fig (4) the leaf base shape showed significant differences. 69% of the grafted cultivars 45% of the seedling cultivars and all of the South African cultivars were obtuse leaf base shape. Only the Sinaria cultivar (seedling cultivar) was the round base shape.

Cecilia (2010) reported variations between all cultivars he tested among leaf blade, apex and base shape. The study revealed that mango leaves are variable in shape and size and even color, a fact reported by Bally italic, (2009) and Fivaz,(2008).

Table (2) leaf length, width and petiole length (cm) of mango cultivars

No	Cultivar	Leaf length	Leaf width	Petiole length
1-	Abu samaka	19.13	5.37	2.23
2-	Nailum	16.80	4.97	2.87
3-	Mitlaky	21.07	5.30	2.73
4-	Mabroka	18.23	5.10	2.43
5-	Zibda	19.13	5.47	2.47
6-	Alphonso	21.37	4.50	3.70
7-	Galbeltowr	19.37	4.77	2.27
8-	Shendi 1	17.90	4.03	3.03
9-	Malgoba	20.10	4.47	3.43
10-	Julik	21.50	5.00	5.23
11-	Timor	21.87	5.50	4.27
12-	Dibsha	24.33	5.33	3.50
13-	Mahmoudi	19.73	5.73	3.03
14-	Walibasha	20.43	5.50	3.17
15-	Bet abu samaka	18.83	5.20	2.37
16-	Segrest	15.47	3.70	2.37
	Average mean	**19.70**	**4.97**	**3.06**
17-	Elkeitt	16.10	5.40	2.83
18-	Elkent	16.60	4.73	2.93
19-	Tommy atkinz	19.33	5.13	3.23
	Average mean	**17.34**	**5.09**	**2.99**
20-	Kutchineer	26.67	5.57	3.17
21-	Bet bady	26.80	6.47	3.77
22-	Wad srear	18.37	3.70	3.27
23-	Sinaria	24.50	7.07	3.40
24-	Shabala	17.20	4.30	2.37
25-	Higazia	16.70	3.70	2.37
26-	Yageen	20.30	5.27	4.60
27-	Taiba	26.63	4.73	2.70
28-	Bizrt shendi	17.23	6.60	4.33
29-	Ras maktoul	28.80	6.70	4.13
30-	Shreefia	25.83	5.23	3.20
	Average mean	**22.64**	**5.39**	**3.39**
	SE ±	**.252**	**.063**	**.075**

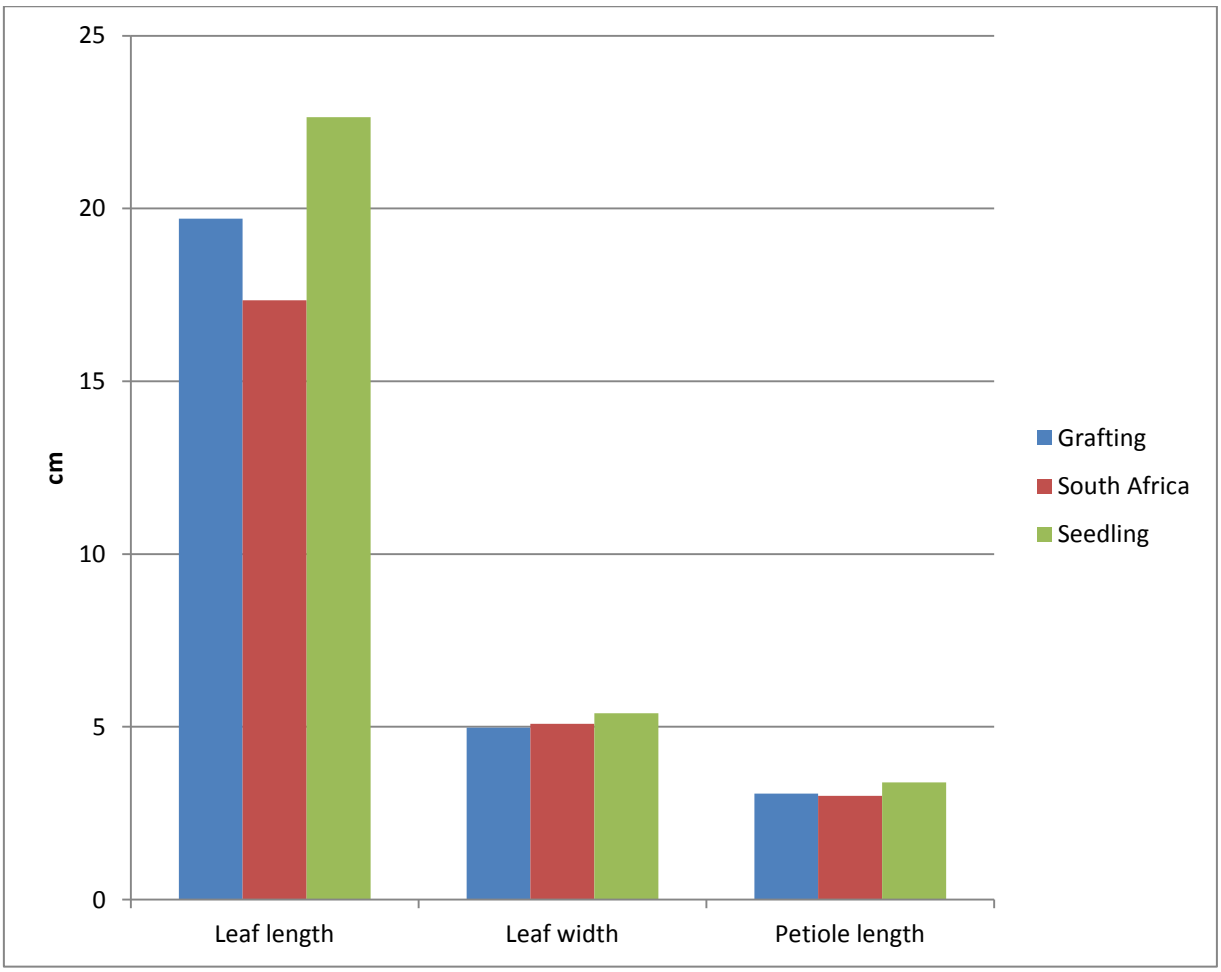


Fig.1. Leaf length, width and petiole length

Table (3) Leaf blade shape, apex shape and base shape of mango cultivars

No	Cultivar	Leaf blade shape	Leaf apex shape	Leaf base shape
1-	Abu samaka	Lanceolate	Acute	Obtuse
2-	Nailum	Elliptic	Acute	Acute
3-	Mitlaky	Elliptic	Acuminate	Obtuse
4-	Mabroka	Elliptic	Acuminate	Obtuse
5-	Zibda	Elliptic	Acuminate	Obtuse
6-	Alphonso	Lanceolate	Acuminate	Obtuse
7-	Galbeltowr	Lanceolate	Acuminate	Obtuse
8-	Shendi 1	Lanceolate	Acute	Acute
9-	Malgoba	Lanceolate	Acuminate	Acute
10-	Julik	Elliptic	Acuminate	Obtuse
11-	Timor	Elliptic	Acuminate	Obtuse
12-	Dibsha	Lanceolate	Acuminate	Obtuse
13-	Mahmoudi	Elliptic	Acute	Obtuse
14-	Walibasha	Elliptic	Acuminate	Obtuse
15-	Bet abu samaka	Lanceolate	Acute	Acute
16-	Segrest	Lanceolate	Acuminate	Acute
17-	Elkeitt	Elliptic	Acute	Obtuse
18-	Elkent	Lanceolate	Acute	Obtuse
19-	Tommy atkinz	Lanceolate	Acuminate	Obtuse
20-	Kutchineer	Lanceolate	Acute	Obtuse
21-	Bet bady	Lanceolate	Acuminate	Acute
22-	Wad srear	Lanceolate	Acute	Acute
23-	Sinaria	Elliptic	Acute	Round
24-	Shabala	Lanceolate	Acute	Obtuse
25-	Higazia	Lanceolate	Acuminate	Obtuse
26-	Yageen	Lanceolate	Acuminate	Acute
27-	Taiba	Lanceolate	Acute	Acute
28-	Bizrt shendi	Lanceolate	Acute	Acute
29-	Ras maktoull	Elliptic	Acute	Obtuse
30-	Shreefia	Elliptic	Acuminate	Obtuse

Lanceolate

Elliptic

Fig2. Leaf shape

Acute

Acuminate

Fig3. Leaf apex shape

Obtuse

Round

Acute

Fig4. Leaf base shape

4.1.1.3 Leaf margin and texture

Table (4) showed the margin and texture of the leaves of mango cultivars tested. Fig (5) two types of leaf margin were observed (wavy and entire). The leaf margin showed no direct relationship between the groups, but it showed a cultivar characteristic.

Three types of leaf texture were observed (coriaceous, chartaceous and membranous). 50% of the cultivars showed coriaceous texture although the texture was a cultivar characteristic (Fig.6)

Variations in leaf margin and texture were reported by Bally italic, (2009) who found that these variations were due to climate, cultural practices and growth stage.

4.1.2 Inflorescences characterization

Most of mango cultivars have terminal inflorescences. Sometimes many panicles rise from the axillary buds (Elgozuli, 2011) and (Abdelrahman, 2009). These findings agreed with the results obtained from the study.

4.1.2.1 Inflorescences length

Table (5) showed the inflorescences length of the 30 mango cultivars. The cultivars differ significantly in the inflorescences length regard less the origin of cultivar. Fig (7) showes the grafted cultivars differ from the seedling cultivars, but showed more or less the same inflorescences length as South African cultivars. The length vary between the grafted cultivars depending on the cultivar showing a length between 37.200 (Dibsha) and 12.033cm (Shendi) with an average length of 24.187cm. With no significant differences from the South African cultivars.

The seedling cultivars showed longer inflorescences compared to the other cultivars with average length of 34.594cm. They showed no significant differences between them ranging from 39.000cm to 30.300cm.

The wide range of Inflorescences length variation due to the cultivar was reported by (Elgozuli, 2011). Who reported a range of 17.6- 34.2 cm and a wider range was mentioned by Morton (1987) who reported a range of 6-40 cm inflorescence length. Regardless the cultivar origin (Abdelrahman, 2009) grouped the inflorescence length three ranges viz 20- 29, 30- 39 and 40-50cm showing the wider range of the inflorescence length (20-50cm).

4.1.2.2 Inflorescences color, shape, density and floral leaves

The color, shape, density and floral leaves of inflorescences of the mango cultivars were shown in (table 6).

Fig (8) all the grafted cultivars showed green inflorescences. With very few ones showing a slight yellow or red color. The three cultivars from South Africa showed dark red color of the inflorescences. The seedling cultivar showed a varying inflorescences color from green red, green, yellow, red, red light and dark red depending on the cultivar. The grafted cultivars showed either conical or pyramidal inflorescences shape, most of the seedling cultivar showed a conical shape with few pyramidal inflorescences shape (30%). The South African cultivar showed a pyramidal inflorescences shape (Fig.9).

Fig (10) the densities of the inflorescences in all cultivars vary between Dense (43%), Sparse (30%) and Medium (27%), a finding reported by (Cecilia, 2010).

No floral leaves existed in all cultivars expect in a very few seedling cultivars 3(grafted) cultivars (Dibsha, Mahmoudi and Nailum and 4 cultivars in the seedling ones Shabala, Shreefia, Taiba and Yageen (Fig.11). As reported by Elgozuli, (2011) indicated the shape of the inflorescence differ with different cultivars either conical or pyramidal as the results of the study showed. The finding reported earlier showed dense to medium inflorescence (Morton, 1987, Elgozuli, 2011).

Table (4) Leaf margin and texture of mango cultivars

No	Cultivar	Leaf margin	Leaf texture
1-	Abu samaka	Entire	Coriaceous
2-	Nailum	Entire	Coriaceous
3-	Mitlaky	Wavy	Chartaceous
4-	Mabroka	Entire	Membranous
5-	Zibda	Entire	Chartaceous
6-	Alphonso	Wavy	Coriaceous
7-	Galbeltowr	Wavy	Membranous
8-	Shendi 1	Entire	Chartaceous
9-	Malgoba	Wavy	Coriaceous
10-	Julik	Wavy	Chartaceous
11-	Timor	Wavy	Coriaceous
12-	Dibsha	Wavy	Chartaceous
13-	Mahmoudi	Entire	Chartaceous
14-	Walibasha	Wavy	Chartaceous
15-	Bet abu samaka	Entire	Coriaceous
16-	Segrest	Entire	Coriaceous
17-	Elkeitt	Entire	Membranous
18-	Elkent	Wavy	Coriaceous
19-	Tommy atkinz	Entire	Chartaceous
20-	Kutchineer	Entire	Chartaceous
21-	Bet bady	Wavy	Membranous
22-	Wad srear	Entire	Coriaceous
23-	Sinaria	Entire	Membranous
24-	Shabala	Entire	Coriaceous
25-	Higazia	Wavy	Coriaceous
26-	Yageen	Wavy	Coriaceous
27-	Taiba	Entire	Coriaceous
28-	Bizrt shendi	Entire	Coriaceous
29-	Ras maktoul	Entire	Coriaceous
30-	Shreefia	Wavy	Membranous

Wavy

Entire

Fig5. Leaf margin

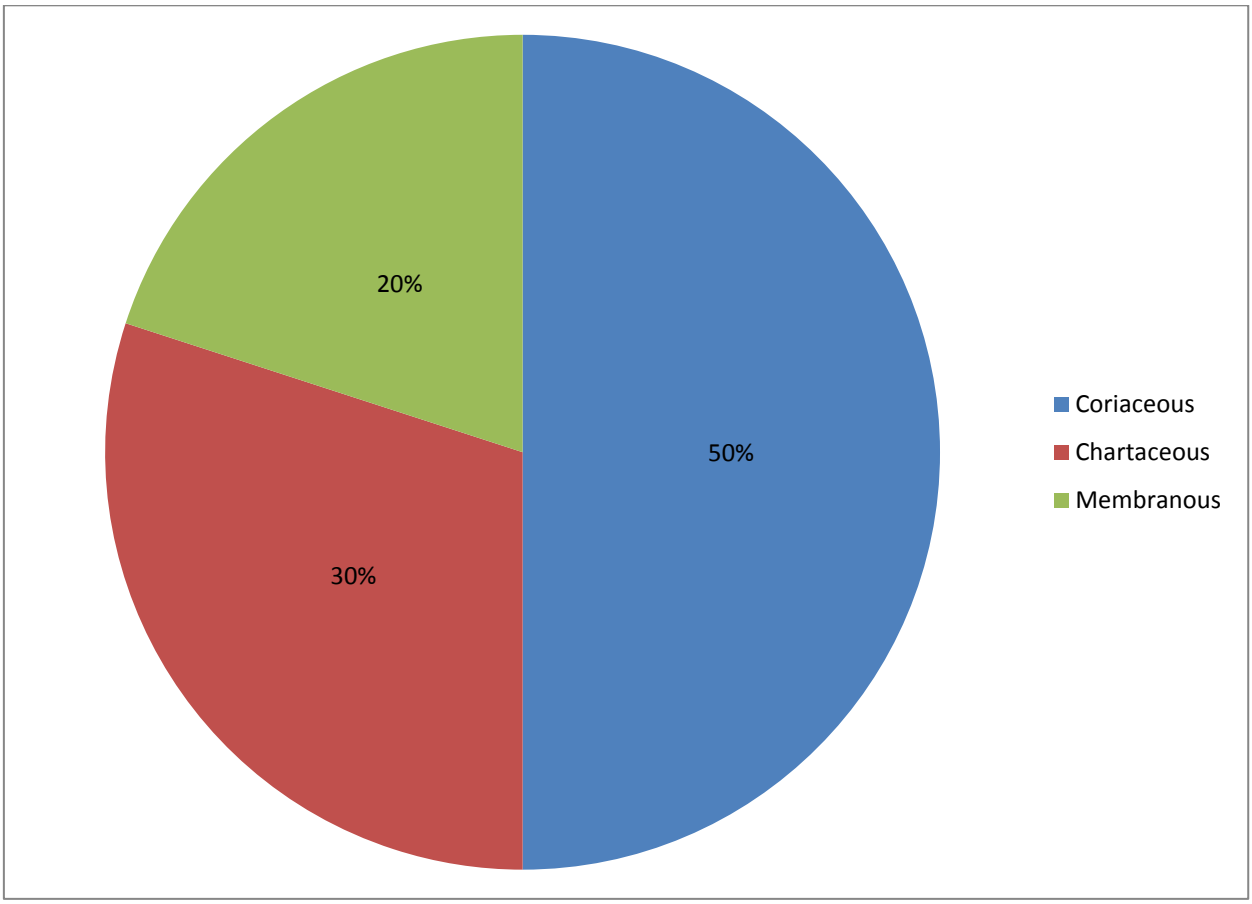


Fig6. Leaf texture

Table (5) Inflorescences length (cm) of mango cultivars

No	Cultivar	Inflorescences length
1-	Abu samaka	19.40
2-	Nailum	20.93
3-	Mitlaky	28.37
4-	Mabroka	16.53
5-	Zibda	25.13
6-	Alphonso	22.90
7-	Galbeltowr	14.73
8-	Shendi 1	12.03
9-	Malgoba	24.57
10-	Julik	31.37
11-	Timor	28.13
12-	Dibsha	37.20
13-	Mahmoudi	35.13
14-	Walibasha	32.97
15-	Bet abu samaka	24.07
16-	Segrest	13.53
	Average mean	**24.18**
17-	Elkeitt	23.67
18-	Elkent	22.37
19-	Tommy atkinz	23.93
	Average mean	**23.32**
20-	Kutchineer	30.87
21-	Bet bady	33.60
22-	Wad srear	35.60
23-	Sinaria	38.60
24-	Shabala	38.07
25-	Higazia	32.27
26-	Yageen	35.83
27-	Taiba	33.77
28-	Bizrt shendi	30.30
29-	Ras maktoul	32.63
30-	Shreefia	39.00
	Average mean	**34.59**
	SE ±	**.66**

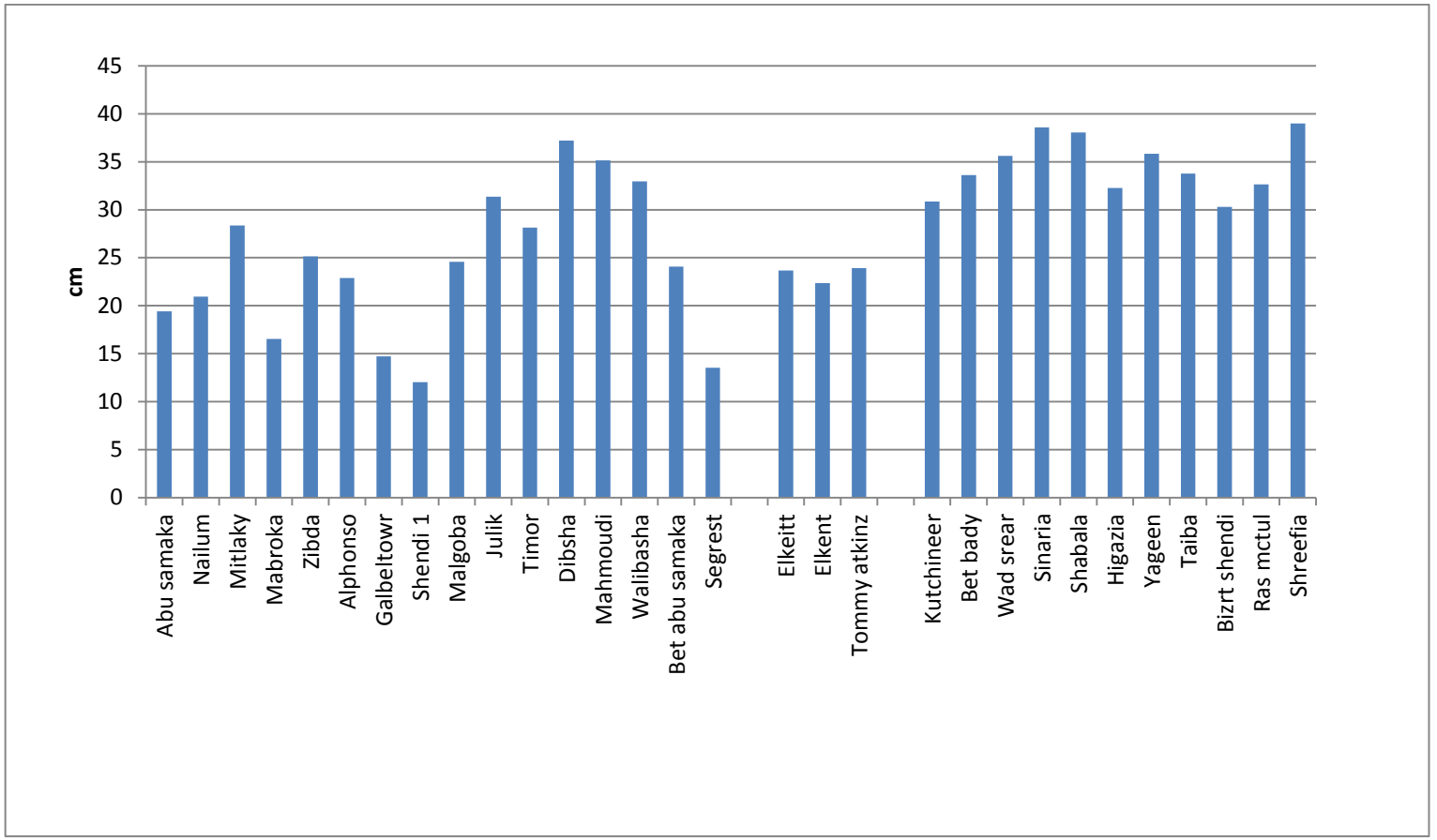


Fig7. Inflorescences length

Table (6) Inflorescences color, shape, density and floral leaves of mango

No	Cultivar	Inflorescences color	Inflorescences shape	Inflorescences density	Floral leaves
1-	Abu samaka	Red light	Pyramidal	Dense	Not exist
2-	Nailum	Red	conical	Dense	Exist
3-	Mitlaky	Greenish yellow	conical	Medium	Not exist
4-	Mabroka	Red light	Pyramidal	Medium	Not exist
5-	Zibda	Green red line	conical	Sparse	Not exist
6-	Alphonso	Red light	Pyramidal	Medium	Not exist
7-	Galbeltowr	Green light	conical	Sparse	Not exist
8-	Shendi 1	Greenish yellow	Pyramidal	Dense	Not exist
9-	Malgoba	Greenish yellow	conical	sparse	Not exist
10-	Julik	Green	conical	sparse	Not exist
11-	Timor	Green red line	conical	Dense	Not exist
12-	Dibsha	Dark red	Pyramidal	Dense	Exist
13-	Mahmoudi	Green	Pyramidal	sparse	Exist
14-	Walibasha	Greenish yellow	Pyramidal	sparse	Not exist
15-	Bet abu samaka	Green red line	conical	Dense	Not exist
16-	Segrest	Red	Pyramidal	Dense	Not exist
17-	Elkeitt	Dark red	pyramidal	Dense	Not exist
18-	Elkent	Dark red	Pyramidal	Dense	Not exist
19-	Tommy atkinz	Dark red	Pyramidal large	Dense	Not exist
20-	Kutchineer	Red	conical	Medium	Not exist
21-	Bet bady	Green red line	Pyramidal	Dense	Not exist
22-	Wad srear	Red light	Pyramidal	Dense	Not exist
23-	Sinaria	Green	conical	Medium	Not exist
24-	Shabala	Red light	conical	Medium	Exist
25-	Higazia	Red light	conical	Medium	Not exist
26-	Yageen	Dark red	conical	sparse	Exist
27-	Taiba	Yellow	conical	sparse	Exist
28-	Bizrt shendi	Red	Pyramidal large	Dense	Not exist
29-	Ras maktoul	Red light	conical	Medium	Not exist
30-	Shreefia	Green	conical	sparse	Exist

Green

Red

Greenish yellow

Fig8. Inflorescences color

Pyramidal

Conical

Fig9. Inflorescences shape



Dense **Medium** **Spare**

Fig10. Inflorescences density


Exist **Not exist**

Fig11. Floral leaves

4.1.3 Fruit characterization

4.1.3.1 Fruit length, width, weight and circumference

Table (7), (Fig.12 and 13) showed the fruit length, width, weight and circumference of mango fruits of all the cultivars tested.

The fruit length showed significant differences ($P \leq 0.05$) between the cultivars, ranging between 21.167 and 7.967cm in length. The grafted cultivars showed the longest ones compared to the others followed by the seedling and the South African cultivars. Abu Samaka, Julik and Segrest showed the longest cultivars giving a length over the average Mitlaky, Shendi, Timor and Walibasha, gave the shortest cultivar below the average. The seedling cultivars showed a little variation between the cultivars fruit length ranging between 15.267 and 10.233cm which are around the average length compaired to the grafted cultivars which gave a very wide range. The South African cultivars showed the shortest fruit length.

As the fruit length, the fruit width showed a significant difference ($P \leq 0.05$) between the cultivars. The grafted cultivars showed a wide variation regarding the fruit width unlike the seedling cultivars with exception of the Sinaria cultivar. The South African cultivars showed an average fruit width shorter than the seedling cultivars and longer than the grafted ones.

The fruit weight and the fruit circumference followed the same trend of the fruit width. The grafted cultivars showed the higher fruit weight and circumference compared to the other. Ras maktoul cultivar showed the highest weight.

The fruit of mango showed varying size and weight and circumferences depending on the cultivars. A finding reported by (Abdelrahman, 2009; Elgozuli, 2011). They reported a length of 7.0- 18cm. Zaied *et al.*, (2007) and Hussaeino *et al.*, (1999) reported variations concerning length and weight of the mango fruit.

They reported these variations in mango genotypes. The study showed that Julik and Segrest have the longest fruit as reported by Abdelrahman, (2009).

4.1.3.2 Fruit shape, apex shape and slope of shoulders

Table (8) showed the shape, apex shape and slope shoulders of the fruits of the cultivars tested.

The fruit shape of the grafted cultivars was almost oblong (62.5%) except for few cultivars with roundish shape (12.5%) and (12.5%) elliptic shape. The shape of the seedling cultivars vary between cultivars depending on the variety. South African cultivars were elliptic and roundish and no oblong fruits observed (Fig.14).

The fruit apex shape followed the same trend of the fruit shape, as (62.5%) of the fruit apex were acute and obtuse in the grafted cultivars, whereas the seedling cultivars showed (64%) oblong fruit apex. The fruit apex of the South African cultivars showed the same shape regardless the cultivars.

Fig (15) recorded the slope of the fruit shoulder differs greatly between the grafted and seedling cultivars. Almost all the grafted cultivar ending in a long cure shoulder where as the seedling cultivars shoulder slope is rising and then rounded. Two of the South Africa cultivars end in a long cure while Elkent cultivar has a rising and then rounded shoulder slope.

The fruit and apex shapes and the slope of shoulders vary greatly between the cultivars. Abdelrahman, (2009) reported these variations among mango genotypes and even among the same cultivar.

Table (7) fruit length, width, circumference (cm) and weight (g) of mango cultivars

No	Cultivar	Fruit length	Fruit width	Fruit weight	Fruit circumference
1-	Abu samaka	16.37	8.73	528.53	27.633
2-	Nailum	12.60	8.73	490.13	27.03
3-	Mitlaky	9.73	6.63	278.10	21.97
4-	Mabroka	11.00	8.73	433.60	26.40
5-	Zibda	10.03	7.50	300.27	23.07
6-	Alphonso	11.40	6.93	249.23	22.33
7-	Galbeltowr	12.27	9.40	505.13	27.87
8-	Shendi 1	8.60	6.10	195.73	20.03
9-	Malgoba	10.10	8.37	481.10	27.43
10-	Julik	21.17	6.90	512.40	21.63
11-	Timor	9.93	6.20	220.83	20.57
12-	Dibsha	12.97	9.10	603.57	29.50
13-	Mahmoudi	13.40	7.53	390.60	23.10
14-	Walibasha	7.97	6.43	187.30	20.03
15-	Bet abu samaka	13.87	10.50	675.50	33.30
16-	Segrest	20.17	10.70	818.17	33.20
	Average mean	**12.59**	**8.03**	**429.38**	**25.31**
17-	Elkeitt	11.53	9.10	474.93	27.30
18-	Elkent	10.83	9.33	459.53	28.30
19-	Tommy atkinz	9.43	7.57	312.23	24.63
	Average mean	**10.93**	**8.67**	**382.23**	**26.74**
20-	Kutchineer	10.83	8.00	317.87	23.60
21-	Bet bady	14.47	11.63	845.23	36.97
22-	Wad srear	10.23	9.80	537.03	30.77
23-	Sinaria	10.93	6.13	245.70	19.67
24-	Shabala	12.90	10.17	648.07	31.80
25-	Higazia	10.40	9.23	482.10	27.90
26-	Yageen	10.77	8.43	385.17	25.77
27-	Taiba	11.10	9.67	619.17	31.20
28-	Bizrt shendi	15.27	8.27	497.20	24.90
29-	Ras maktoul	13.77	11.93	1154.43	39.47
30-	Shreefia	12.03	10.80	747.23	33.27
	Average mean	**12.06**	**9.46**	**589.01**	**29.57**
	SE ±	**.18**	**.07**	**13.77**	**.24**

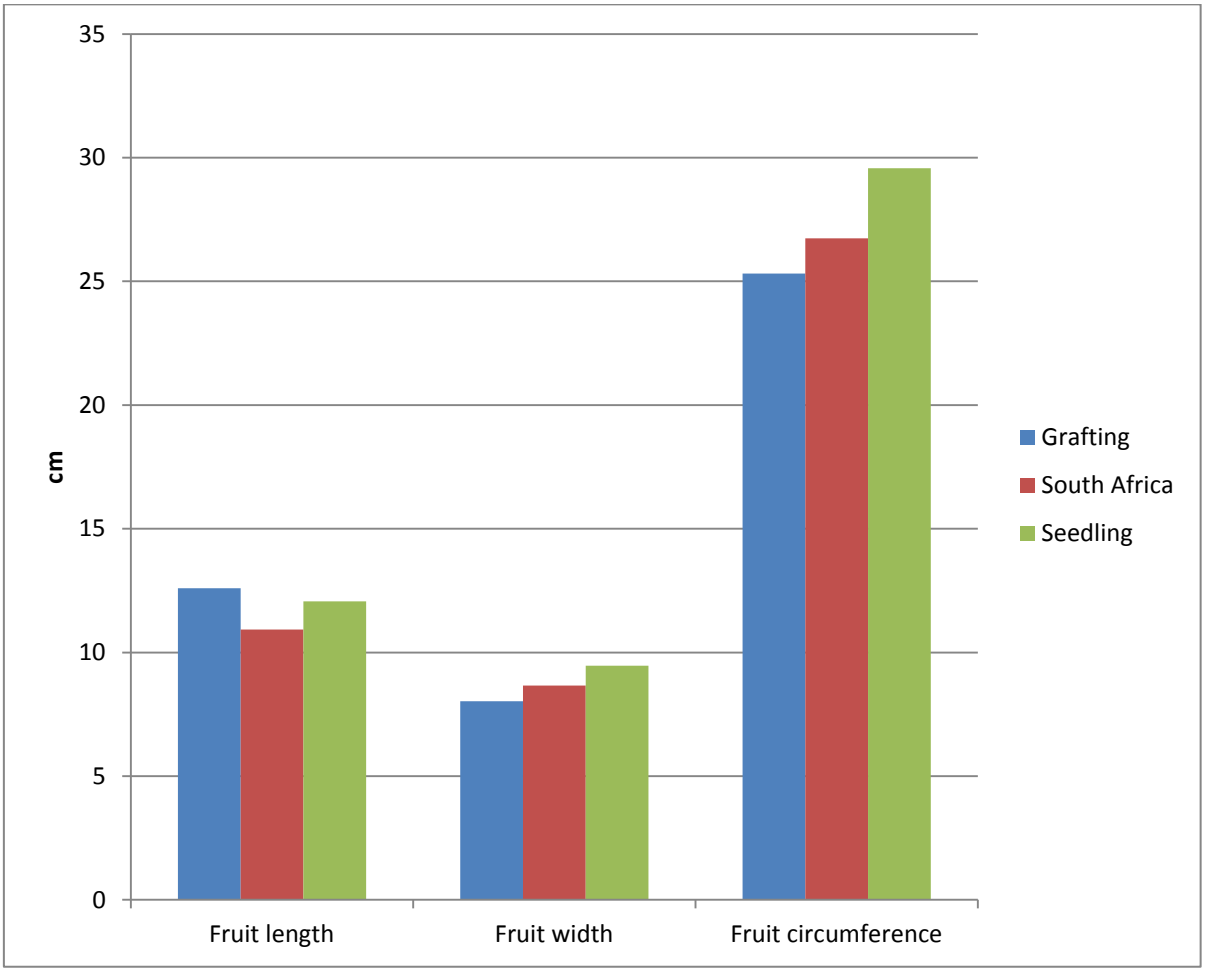


Fig.12.Fruit length, width and circumference

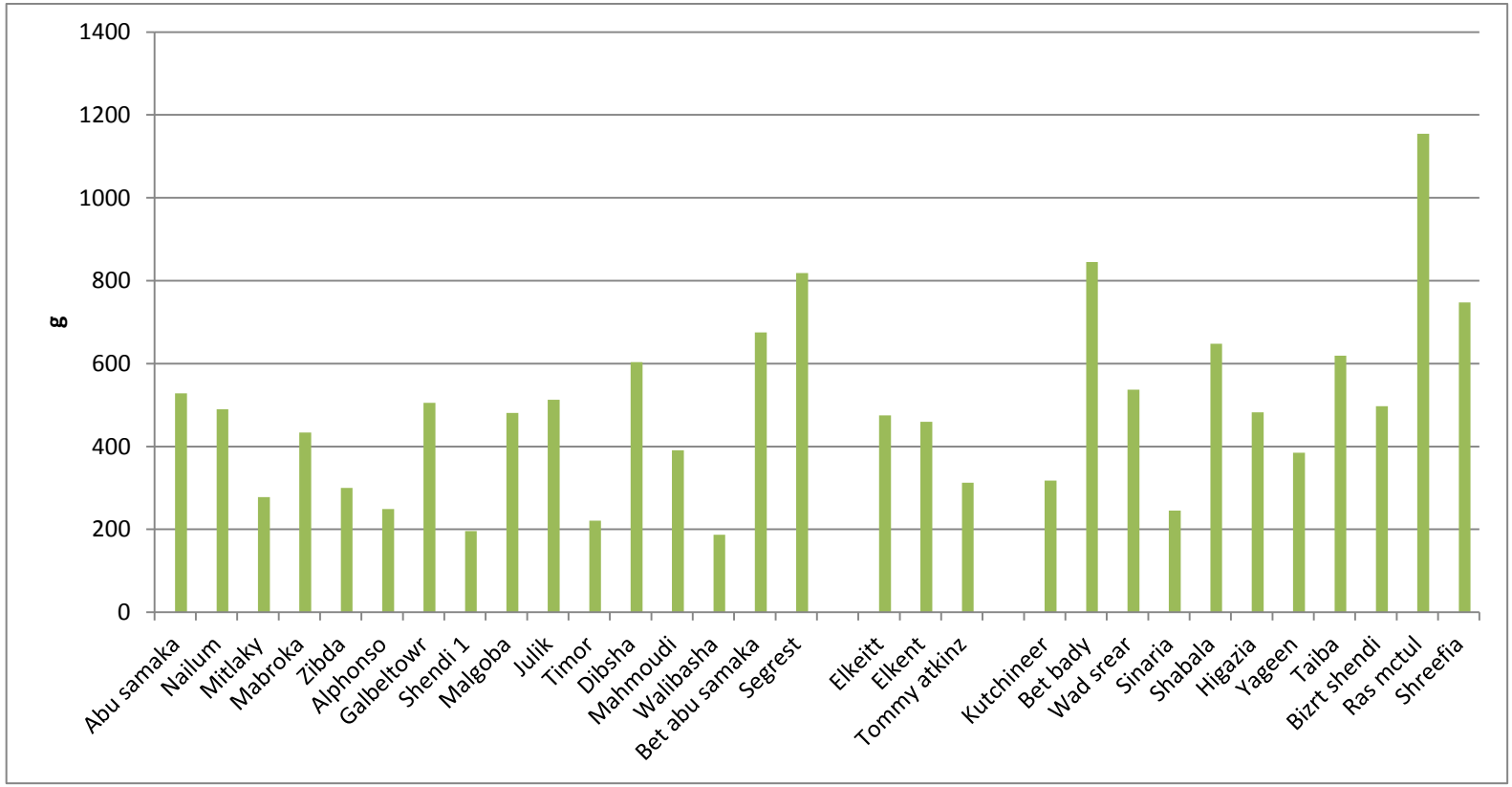
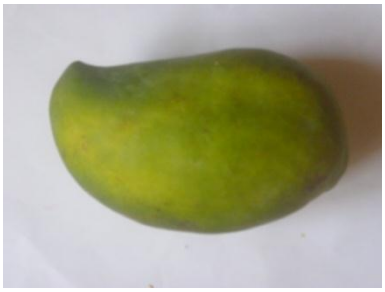


Fig13. Fruit weight

Table (8) Fruit shape, apex shape and slope of shoulders of mango cultivars

No	Cultivar	Fruit shape	Fruit apex shape	Fruit slope shoulder
1-	Abu samaka	Oblong	Acute	Sloping abruptly
2-	Nailum	Elliptic	Obtuse	Ending in along cure
3-	Mitlaky	Elliptic	Obtuse	Ending in along cure
4-	Mabroka	Oblong	Acute	Rising and then rounded
5-	Zibda	Oblong	Acute	Ending in along cure
6-	Alphonso	Roundish	Obtuse	Rising and then rounded
7-	Galbeltowr	Roundish	Obtuse	Rising and then rounded
8-	Shendi 1	Oblong	Acute	Ending in along cure
9-	Malgoba	Roundish	Obtuse	Rising and then rounded
10-	Julik	Oblong	Acute	Ending in along cure
11-	Timor	Oblong	Acute	Ending in along cure
12-	Dibsha	Oblong	Acute	Rising and then rounded
13-	Mahmoudi	Oblong	Acute	Ending in along cure
14-	Walibasha	Roundish	Obtuse	Ending in along cure
15-	Bet abu samaka	Oblong	Acute	Rising and then rounded
16-	Segrest	Oblong	Acute	Ending in along cure
17-	Elkeitt	Elliptic	Obtuse	Ending in along cure
18-	Elkent	Roundish	Obtuse	Rising and then rounded
19-	Tommy atkinz	Roundish	Obtuse	Ending in along cure
20-	Kutchineer	Oblong	Acute	Rising and then rounded
21-	Bet bady	Roundish	Obtuse	Rising and then rounded
22-	Wad srear	Roundish	Obtuse	Rising and then rounded
23-	Sinaria	Oblong	Acute	Ending in along cure
24-	Shabala	Roundish	Obtuse	Rising and then rounded
25-	Higazia	Roundish	Obtuse	Rising and then rounded
26-	Yageen	Elliptic	Obtuse	Rising and then rounded
27-	Taiba	Elliptic	Acute	Rising and then rounded
28-	Bizrt shendi	Oblong	Acute	Sloping abruptly
29-	Ras maktoul	Roundish	Obtuse	Rising and then rounded
30-	Shreefia	Oblong	Acute	Rising and then rounded



Oblong

Roundish

Elliptic

Fig14. Fruit shape

Rising and then rounded

Sloping abruptly

Ending in along cure

Fig15. Fruit slop shoulder

4.1.3.3 Fruit beak type and sinus type

The fruit beak type and sinus type were shown in (Table 9).

The two parameters showed a different trend regarding the cultivar. No significant differences between the grafted, South African and seedling cultivars. Most of the cultivars showed a shallow or absent sinus with very few cultivars deep sinus (Fig.16 – 17).

The beak type and sinus type of the fruit is the most characteristic feature of the fruit. Morton, (1987) reported that the beak may be prominent or represented merely as dob. These findings were in accordance with the findings of this study. Abdelrahman, (2009) and Elgozuli, (2011) reported the same finding.

4.1.3.4 Skin weight percentage and color

The weight% and color of skin of the fruit were shown in (Table 10).

The grafted cultivars skin weight% showed a wide range of the percentage (9.6-19.7%) compared to the other cultivars with a narrow range (9.5-14.3%) in the seedling cultivars and (12.5-16.5%) in South African cultivars. The average skin weight% of the South African cultivar was higher (14.2%) compared to the local cultivars: (13.6%) The grafted and (12.3%) seedling cultivars.

The colors of the skin also vary greatly between cultivars with the green and yellow colors among all the cultivars regardless the cultivar either grafted or seedling. The skin color of the South African cultivar showed different color from the local cultivar from yellow, green yellow, red, red yellow and red green colors.

Makherjee (1997) reported that the skin weight% and color at maturity is genotypes dependant. The rind weight and thickness vary greatly from 0.5mm to 2.5mm (Abdelrahman, 2009). The results obtained showed that the skin color of

mango fruits ranged from green, yellowish green, yellow and orange a finding coincide with the findings of (Elgozuli, 2011) and Campbell, (1992).

4.1.3.5 Pulp weight percentage, texture and color

Table (11) showed the weight percentage texture and color of the mango fruit pulp.

Fig (18) the pulp content % ranged from 72.2 to 85.3% of the total weight of the fruit in the grafted cultivars. Seven cultivars of the study group have more than 80% pulp, these cultivars include Julik, Galpeltowr and Bet abusamaka with an average % of 79.4% of the total fruit weight. South African cultivars showed an average pulp percent of more than 80% which is lower than most of the grafted cultivars. Likewise, all the seedling cultivars showed a high pulp percent (≥ 80%) except Kutchineer and Sinaria with a total average of 81.7%.

The pulp textures vary with the cultivar under test from firm, soft and juicy. The grafted cultivars showed a very high variation with 7 cultivars firm, 5 soft, 4 juicy. The three South African cultivars showed a firm pulp texture and about 50% of the seedling cultivars have a firm texture. The firm pulp texture was the dominant in more than 50% of the cultivars tested.

The pulp color also vary with in to the cultivar tested, the yellow color is the most color observed among the grafted and seedling cultivars whereas the South African cultivars showed an orange pulp color (Fig.19)

The pulp weight% texture and color of the ripe fruit vary greatly among the cultivar tested. The findings were reported by (Elgozuli, 2011) who showed that the color of the pulp is normally yellow to yellow orange with soft and intermediate soft texture. The pulp weight% depends on the size, weight and length of the fruit beside the weight% of the skin and seed. This parameter is a cultivar characteristic. A finding reported by (Elgozuli, 2011).

Table (9) Fruit beak type and sinus type of mango cultivars

No	Cultivar	Fruit beak type	Fruit sinus type
1-	Abu samaka	Mammiform	Shallow
2-	Nailum	Point	Shallow
3-	Mitlaky	Absent	Absent
4-	Mabroka	Mammiform	Deep
5-	Zibda	Prominent	Shallow
6-	Alphonso	Point	Absent
7-	Galbeltowr	Prominent	Shallow
8-	Shendi 1	Mammiform	Deep
9-	Malgoba	Point	Absent
10-	Julik	Mammiform	Shallow
11-	Timor	Point	Shallow
12-	Dibsha	Mammiform	Deep
13-	Mahmoudi	Mammiform	Shallow
14-	Walibasha	Absent	Absent
15-	Bet abu samaka	Mammiform	Absent
16-	Segrest	Mammiform	Shallow
17-	Elkeitt	Prominent	Absent
18-	Elkent	Point	Absent
19-	Tommy atkinz	Absent	Absent
20-	Kutchineer	Point	Shallow
21-	Bet bady	Prominent	Absent
22-	Wad srear	Absent	Absent
23-	Sinaria	Mammiform	Deep
24-	Shabala	Prominent	Absent
25-	Higazia	Absent	Shallow
26-	Yageen	Prominent	Absent
27-	Taiba	Mammiform	Absent
28-	Bizrt shendi	Mammiform	Deep
29-	Ras maktoul	Point	Shallow
30-	Shreefia	Absent	Deep

Mammiform

Prominent

Point

Absent

Fig16. Fruit beak type

Shallow

Deep

Absent

Fig17. Fruit sinus type

Table (10) Skin weight percentage and color of mango cultivars

No	Cultivar	Skin weight	Skin color
1-	Abu samaka	14.10	Green-yellow
2-	Nailum	13.90	Yellow
3-	Mitlaky	16.10	Green
4-	Mabroka	13.70	Green-yellow
5-	Zibda	12. 00	Light yellow
6-	Alphonso	13.10	Yellow
7-	Galbeltowr	11. 00	Green
8-	Shendi 1	9.80	Yellow
9-	Malgoba	16.40	Green
10-	Julik	9.60	Green-yellow
11-	Timor	19.70	Green
12-	Dibsha	15.10	Green-yellow
13-	Mahmoudi	11.90	Yellow
14-	Walibasha	14.40	Green
15-	Bet abu samaka	11.30	Green-yellow
16-	Segrest	15.90	Green
	Average mean	**13.60**	
17-	Elkeitt	16.50	Green-yellow
18-	Elkent	13.60	Red yellow
19-	Tommy atkinz	12.50	Red
	Average mean	**14.20**	
20-	Kutchineer	13.50	Orange
21-	Bet bady	13.20	Yellow
22-	Wad srear	13.50	Green
23-	Sinaria	14.30	Yellow
24-	Shabala	13.60	Green-yellow
25-	Higazia	9.50	Green
26-	Yageen	13.40	Yellow
27-	Taiba	10.40	Yellow
28-	Bizrt shendi	10.60	Green-yellow
29-	Ras maktoul	10.10	Yellow
30-	Shreefia	13.10	Green
	Average mean	**12.30**	
	SE ±	**1.78**	

Table (11) Pulp weight percentage, texture and color of mango cultivars

No	Cultivar	Pulp weight	Pulp texture	Pulp color
1-	Abu samaka	81.90	Firm	Yellow
2-	Nailum	78.40	Juicy	Orange
3-	Mitlaky	77.20	Soft	Yellow-orange
4-	Mabroka	79.80	Firm	Yellow
5-	Zibda	79.60	Juicy	Light yellow
6-	Alphonso	79.40	Juicy	Light yellow
7-	Galbeltowr	83.60	Soft	Yellow
8-	Shendi 1	80. 00	Juicy	Orange
9-	Malgoba	73.10	Firm	Light yellow
10-	Julik	85.30	Soft	Orange
11-	Timor	72.20	Soft	Yellow-orange
12-	Dibsha	79.80	Soft	Light yellow
13-	Mahmoudi	82.10	Firm	Orange
14-	Walibasha	73.80	Firm	Yellow
15-	Bet abu samaka	83.10	Firm	Yellow
16-	Segrest	80.90	Firm	Yellow-orange
	Average mean	**79.40**		
17-	Elkeitt	80.80	Firm	Yellow
18-	Elkent	80.10	Firm	Orange
19-	Tommy atkinz	80.60	Firm	Orange
	Average mean	**80.50**		
20-	Kutchineer	74.50	Firm	Orange
21-	Bet bady	82.80	Soft	Orange
22-	Wad srear	82.40	Soft	Yellow-orange
23-	Sinaria	76. 00	Firm	Yellow
24-	Shabala	81.40	Firm	Yellow
25-	Higazia	81.80	Firm	Yellow
26-	Yageen	80.40	Firm	Yellow
27-	Taiba	87.30	Juicy	Yellow-orange
28-	Bizrt shendi	82. 04	Soft	Orange
29-	Ras maktoul	87. 00	Juicy	Orange
30-	Shreefia	82.40	Firm	Yellow
	Average mean	**81.70**		
	SE ±	**12.12**		

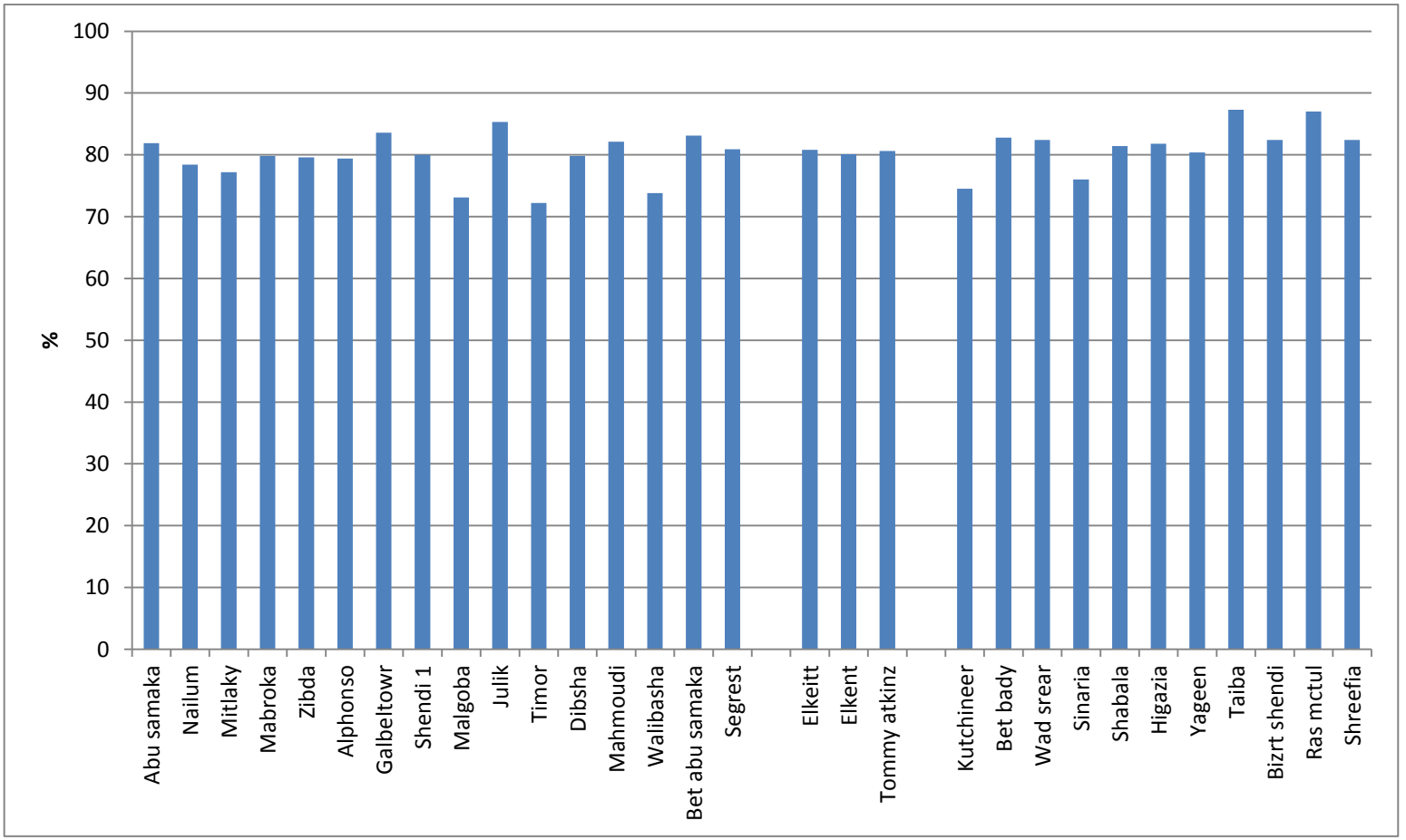
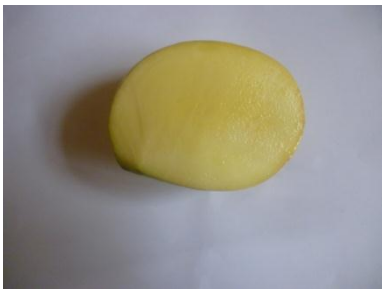


Fig18. Pulp weight percentage

Orange

Yellow

Yellow orange



Light yellow

Fig19. Pulp color

4.1.3.6 Fiber weight percentage

Table (12) the fiber content of the fruits showed a significant differences between the cultivars.

Alphonso showed the lowest fiber content (7.0%) followed by Dibsha and Zibda with no significant differences between them. The grafted cultivars vary in their fiber content ranging from (7.0 to 42.3%) with an average of (27.9%). South African cultivars showed very high fiber content (45%) compared to the other cultivars either grafted or seedling cultivars which the last showed the lowest fiber content (23.4%).

The pulp fiber content showed great variations in quantity and quality of mango cultivars. Fibers were either very fine with less percentage in the pulp as in Abusamaka or thick with high percentage as in Kutchineer. (Elgozuli, 2011). These findings agree with the result of the study as the average fiber percentage in the grafted cultivar was less than of the seed cultivars. Abdelrahman, (2009) reported a range of fiber% of 0.3 to 20% which is very low compared to a range of 7 to 57.5 in this study (Fig.20).

4.1.4 Seed characterization

4.1.4.1 Seed length, width, thickness (cm) and weight (g)

Table (13) showed the length, width, thickness and weight% of the seed of the mango cultivars.

Julik cultivar showed the longest seed (16.433) followed by Segrest and Abu samaka (15.033 and 12.967 respectively). With grafted cultivars seed length average of (9.658). South African cultivars showed a moderate seed length compared to the other cultivars. The seedling cultivars average (9.179) showed a narrow seed length range between (7.533 – 12.533).

Seed width did not vary greatly among the cultivars specially the cultivated cultivars which was around 3.743cm and 4.578 – 4.339 for the seed width in South African and seedling cultivars respectively. Bet bady cultivar showed the widest seed among all the cultivars. Julik was the smallest one (2.767) although it was the longer one. Malgoba cultivars showed the largest seed thickness (2.433) followed by Nailum and Bet abusamaka with the same thickness (2.333) with grafted cultivars seed thickness average of (1.939) cm. South African cultivars showed almost the same seed thickness which is lower than the other cultivars. The seedling cultivars average (2.036).

Kutchineer cultivar showed the heaviest cultivar (37.900) which is very heavy compaired to the others. Except Malgoba (50.767) and Nailum (37.867) for the grafted cultivars and Higazia (41.833) for the seedling cultivars. South African cultivars showed the weight among the groups. Although these cultivars showed a heavy seed weight, the percentage of the seeds from the total fruit weight.

As reported by (Elgozuli, 2011), length, width, thickness and weight of the mango seeds were varying among cultivars. Abdelrahman (2009) reported that the seed length is proportional to the fruit length, but the width and thickness of the seeds have no definite pattern. The weight of the seeds was found to be related to the weight of the fruit as a large fruit has heavy seed weight (Abdelrahman, 2009).

4.1.4.2 Seed pattern of venation and veins

Mango seeds also showed significant variations in the pattern of venation and veins (Table 14). Grafted varieties differ in the pattern of venation where almost 50% of the seeds have a parallel venation. The variations within the seedling varieties were large than other groups studied. Three quarters were forked (Fig.21). The seed veins follow the same pattern at the venation. As more than 50% of the grafted cultivars have depressed veins and more than 75% of the seedling varieties have a veins leveled with the surface.

Table (12) Fruit fiber weight percentage of mango cultivars

No	Cultivar	Fiber weight
1-	Abu samaka	17.80
2-	Nailum	18.20
3-	Mitlaky	29.40
4-	Mabroka	30.60
5-	Zibda	13.30
6-	Alphonso	7. 00
7-	Galbeltowr	38.10
8-	Shendi 1	26.20
9-	Malgoba	39.80
10-	Julik	24.50
11-	Timor	29.20
12-	Dibsha	17.50
13-	Mahmoudi	42.30
14-	Walibasha	32.20
15-	Bet abu samaka	40.40
16-	Segrest	39.30
	Average mean	**27.90**
17-	Elkeitt	57.30
18-	Elkent	34.80
19-	Tommy atkinz	42.90
	Average mean	**45.00**
20-	Kutchineer	26.90
21-	Bet bady	20.50
22-	Wad srear	18.20
23-	Sinaria	33.60
24-	Shabala	40.60
25-	Higazia	16.40
26-	Yageen	14.90
27-	Taiba	25.90
28-	Bizrt shendi	19.30
29-	Ras maktoul	13.40
30-	Shreefia	27.50
	Average mean	**23.40**
	SE ±	**.69**

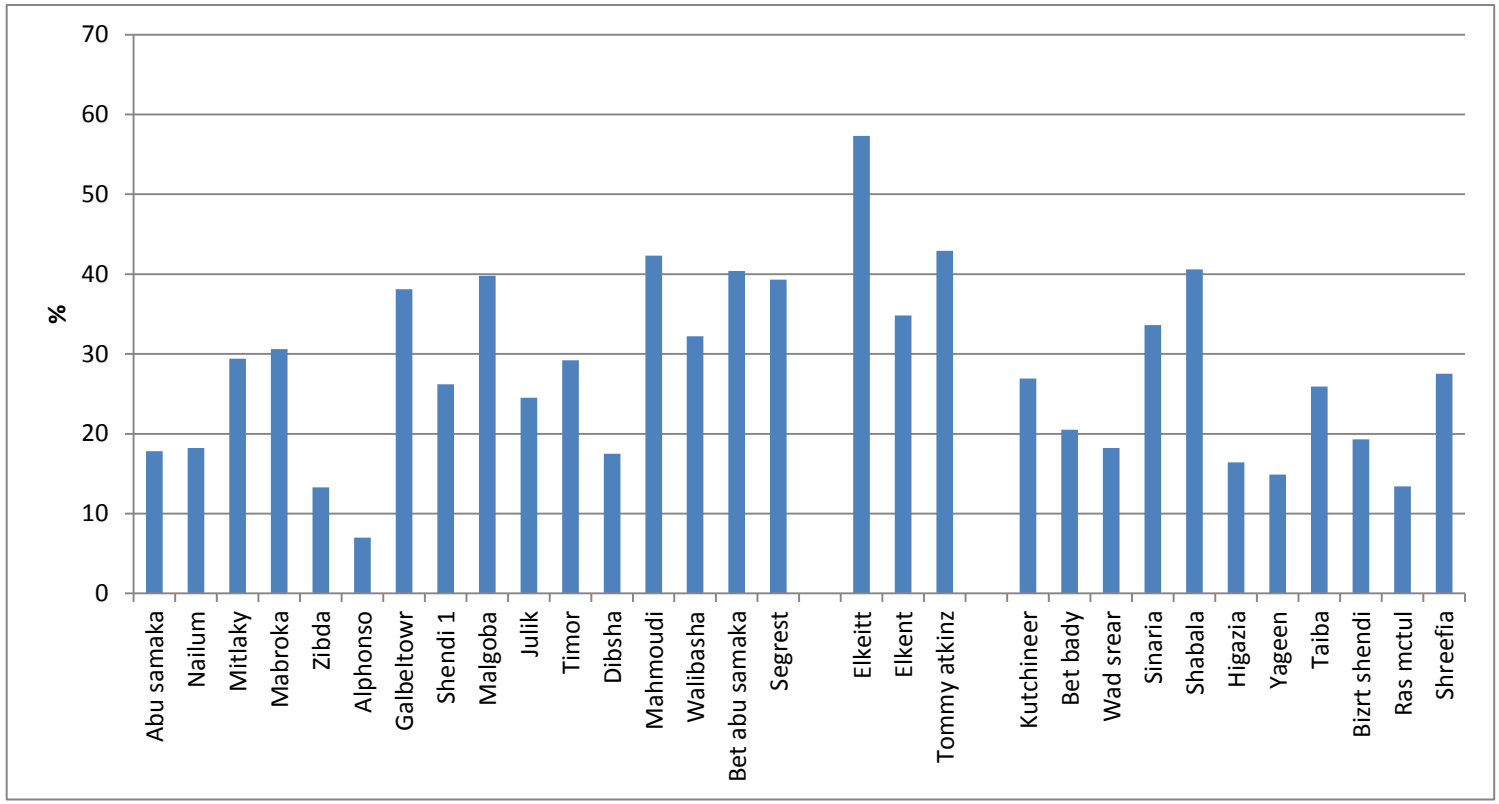


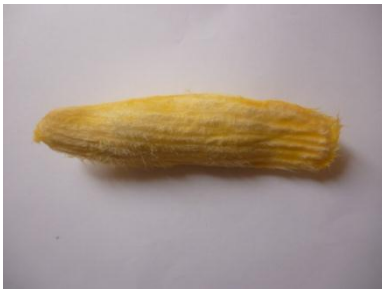
Fig20. Fiber weight percentage

Table (13) Seed length, width, thickness (cm) and weight (g) of mango cultivars

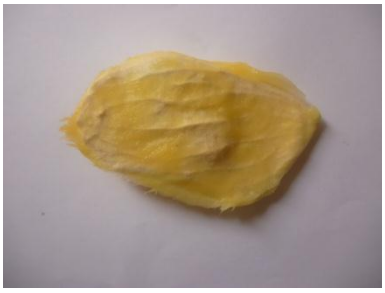
No	Cultivar	Seed length	Seed width	Seed thickness	Seed weight
1-	Abu samaka	12.97	4.13	1.80	22.50
2-	Nailum	8.63	3.70	2.33	37.87
3-	Mitlaky	8.07	3.60	1.47	18.53
4-	Mabroka	8.43	3.57	1.97	28.20
5-	Zibda	7.67	3.77	1.83	25.37
6-	Alphonso	6.17	3.43	1.83	18.77
7-	Galbeltowr	9.43	4.30	2.00	27.20
8-	Shendi 1	6.87	3.27	1.80	20.07
9-	Malgoba	8.40	4.43	2.43	50.77
10-	Julik	16.43	2.77	1.77	25.83
11-	Timor	7.57	3.50	1.90	17.83
12-	Dibsha	10.23	3.80	2.07	31.07
13-	Mahmoudi	11.33	3.57	1.67	23.47
14-	Walibasha	6.53	3.50	1.70	22.10
15-	Bet abu samaka	10.77	4.33	2.33	37.97
16-	Segrest	15.03	4.23	2.13	26.57
	Average mean	**9.65**	**3.74**	**1.93**	**27.13**
17-	Elkeitt	10.73	4.80	1.50	12.87
18-	Elkent	8.50	4.43	1.60	19.27
19-	Tommy atkinz	7.87	4.50	1.77	21.43
	Average mean	**9.03**	**4.58**	**1.62**	**17.86**
20-	Kutchineer	8.57	4.33	2.20	37.90
21-	Bet bady	11.23	6.13	2.17	33.60
22-	Wad srear	7.87	3.87	1.90	22.07
23-	Sinaria	9.00	3.27	1.83	23.93
24-	Shabala	9.73	4.23	2.23	32.80
25-	Higazia	8.03	3.97	2.43	41.83
26-	Yageen	8.50	4.23	1.57	24.10
27-	Taiba	7.53	4.30	1.47	14.03
28-	Bizrt shendi	12.53	4.17	2.10	35.07
29-	Ras maktoul	9.00	4.70	2.43	34.33
30-	Shreefia	8.97	4.53	2.07	33.73
	Average mean	**9.17**	**4.33**	**2.03**	**30.31**
	SE ±	**.10**	**.04**	**.02**	**.86**

Table (14) Seed pattern of venation and veins of mango cultivars

No	Cultivar	Seed pattern of venation	Seed veins
1-	Abu samaka	Parallel	Level with surface
2-	Nailum	Parallel	Elevated
3-	Mitlaky	Parallel	Level with surface
4-	Mabroka	Forked	Depressed
5-	Zibda	Forked	Elevated
6-	Alphonso	Forked	Depressed
7-	Galbeltowr	Parallel	Level with surface
8-	Shendi 1	Forked	Elevated
9-	Malgoba	Forked	Level with surface
10-	Julik	Parallel	Depressed
11-	Timor	Forked	Depressed
12-	Dibsha	Parallel	Depressed
13-	Mahmoudi	Parallel	Elevated
14-	Walibasha	Forked	Level with surface
15-	Bet abu samaka	Parallel	Depressed
16-	Segrest	Parallel	Depressed
17-	Elkeitt	Forked	Level with surface
18-	Elkent	Parallel	Depressed
19-	Tommy atkinz	Parallel	Depressed
20-	Kutchineer	Forked	Depressed
21-	Bet bady	Forked	Elevated
22-	Wad srear	Forked	Elevated
23-	Sinaria	Parallel	Depressed
24-	Shabala	Forked	Elevated
25-	Higazia	Forked	Depressed
26-	Yageen	Parallel	Depressed
27-	Taiba	Forked	Level with surface
28-	Bizrt shendi	Parallel	Elevated
29-	Ras maktoul	Forked	Elevated
30-	Shreefia	Forked	Elevated



Parallel



Forked

Fig21. Seed pattern of venation

Table (15) Fruit, Skin, Pulp, Fiber and Seed weight percentage

N0	Cultivar	Fruit weight (g)	Skin weight	Pulp weight	Fiber weight	Seed weight
1-	Abu samaka	528.53	14.10	81.90	17.80	4.30
2-	Nailum	490.13	13.90	78.40	18.20	7.70
3-	Mitlaky	278.10	16.10	77.20	29.40	6.70
4-	Mabroka	433.60	13.70	79.80	30.60	6.50
5-	Zibda	300.27	12.00	79.60	13.30	8.40
6-	Alphonso	249.23	13.10	79.40	7. 00	7.50
7-	Galbeltowr	505.13	11. 00	83.60	38.10	5.40
8-	Shendi 1	195.73	9.80	80. 00	26.20	10.20
9-	Malgoba	481.10	16.40	73.10	39.80	10.50
10-	Julik	512.40	9.60	85.30	24.50	5.10
11-	Timor	220.83	19.70	72.20	29.20	8.10
12-	Dibsha	603.57	15.10	79.80	17.50	5.10
13-	Mahmoudi	390.60	11.90	82.10	42.30	6. 00
14-	Walibasha	187.30	14.40	73.80	32.20	11.80
15-	Bet abu samaka	675.50	11.30	83.10	40.40	5.60
16-	Segrest	818.17	15.90	80.90	39.30	3.20
	Average mean	**429.38**	**13.60**	**79.40**	**27.90**	**7. 00**
17-	Elkeitt	474.93	16.50	80.80	57.30	2.70
18-	Elkent	459.53	13.60	80.10	34.80	6.30
19-	Tommy atkinz	312.23	12.50	80.60	42.90	6.90
	Average mean	**382.23**	**14.20**	**80.50**	**45.00**	**5.30**
20-	Kutchineer	317.87	13.50	74.50	26.90	12. 0
21-	Bet bady	845.23	13.20	82.80	20.50	4. 00
22-	Wad srear	537.03	13.50	82.40	18.20	4.10
23-	Sinaria	245.70	14.30	76. 00	33.60	9.70
24-	Shabala	648.07	13.60	81.40	40.60	5.00
25-	Higazia	482.10	9.50	81.80	16.40	8.70
26-	Yageen	385.17	13.40	80.40	14.90	6.20
27-	Taiba	619.17	10.40	87.30	25.90	2.30
28-	Bizrt shendi	497.20	10.60	82.40	19.30	7. 00
29-	Ras maktoul	1154.43	10.10	87. 00	13.40	2.9 0
30-	Shreefia	747.23	13.10	82.40	27.50	4.50
	Average mean	**589.01**	**12.30**	**81.70**	**23.40**	**6. 00**
	SE ±	**13.77**	**1.78**	**12.12**	**.69**	**.87**

4.2 The key for the identification of mango (Mangifera indica L.) cultivars based on leaf morphology

A key for the identification of mango cultivars in Sudan based on leaf characteristics.

The mango leaf length verge from less than 15 cm to more than 26 cm. The leaf length was subdivided to 6 groups, each group include a number of cultivars. The first step of the identification was grouping the cultivars depending on the leaf length.

The second step of the identification was based on the leaf width. The leaf width was grouped into 5 groups. Each leaf length group was subjected to the analysis with the leaf width.

Based on the leaf length and leaf width each group was subdivided with the petiole length which was divided into 6 categories.

Step 4 of the key is to identify the previous groups on the bases of leaf blade shape and then for their grouping according to the leaf apex shape and finally leaf texture.

At any step of the identification some cultivars were separated from the other ending with one cultivars at any of the steps of the key.

Finally each cultivar was identified at one of the steps followed.

The summary of cultivars identification was shown in the list of symbols.

Step (I) Leaf length**:-**

L1	L2	L3	L4	L5	L6	L7
> 15	**16 - < 18**	**18 - < 20**	**20 - < 22**	**22 - <24**	**24 - < 26**	**> 26**
Segrest	Bizrt shendi	Abu samaka	Alphonso		Dibsha	Bet bady
	Higazia	Bet abusamaka	Julik		Shreefia	Kutchineer
	Nailum	Galbeltowr	Malgoba		Sinaria	Ras maktoul
	Shabala	Mabroka	Mitlaki			Taiba
	Shendi 1	Mahmoudi	Timor			
		Wad srear	Walibasha			
		Zibda	Yageen			

***L: length**

Step (II) Leaf width **:-**

Length	W1	W2	W3	W4	W5
	3.5 - < 4.5	**4.5 - < 5.5**	**5.5 - < 6.5**	**6.5 - < 7.5**	**> 7.5**
L2	Higazia	**Nailum**		**Bizrt shendi**	
16 - < 18	Shabala				
	Shendi 1				
L3	**Wad srear**	Abu samaka	Bet abu samaka		
18 - < 20		Gelbeltowr	Mahmoudi		
		Mabroka			
		Zibda			
L4	**Malgoba**	Alphonso	Timor		
20 - < 22		Julik	Wali basha		
		Mitlaki			
		Yageen			
L6		Dibsha		**Sinaria**	
24 - < 26		Shreefia			
L7		**Taiba**	Bet bady	Ras maktoul	
> 26			Kutchineer		

*** W: width**

Step (III) Petiole length **: -**

Length - Width	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
	2 - < 2.5	**2.5 - < 3**	**3 - < 3.5**	**3.5 - < 4**	**4 - < 4.5**	**> 4.5**
L2 W1	Higazia		**Shendi 1**			
L2 : 16 - <18	Shabala					
W1 : 3.5 - < 4.5						
L3 W2	Abu samaka					
L3 : 18 - < 20	Galbeltowr					
W2 : 4.5 - < 5.5	Mabroka					
	Zibda					
L3 W3	**Bet abusamaka**		**Mahmoudi**			
L3 : 18 - < 20						
W3 : 5.5 - < 6.5						
L4 W2		**Mitlaky**		**Alphonso**		Julik
L4 : 20 - < 22						Yageen
W2 : 4.5 - < 5.5						
L4 W3			**Walibasha**		**Timor**	
L4 : 20 - < 22						
W3 : 5.5 - < 6.5						
L6 W2			**Shreefia**	**Dibsha**		
L6 : 24 - < 26						
W2 : 4.5 - < 5.5						
L7 W3			**Kutchineer**	**Bet bady**		
L7 : > 26						
W3 : 5.5 - < 6.5						

***P: petiole**

Step (IV) Leaf blade shape :-

Length - Width –Petiole	**B1**	**B2**
	Lanceolate	**Elliptic**
L2 W1 P1	Higazia	
L2 : 16 - < 18	Shabala	
W1 : 3.5 - < 4.5		
P1 : 2 - < 2.5		
L3 W2 P1	Abu samaka	Mabroka
L3 : 18 - < 20	Galbeltowr	Zibda
W2 : 4.5 - < 5.5		
P1 : 2 - < 2.5		
L4 W2 P6	**Yageen**	**Julik**
L4 : 20 - < 22		
W2 : 4.5 - < 5.5		
P6 : > 4.5		

***B: blade shape**

Step (V) Leaf apex shape **: -**

Length - Width – Petiole **Blade shape**	**A1** **Acute**	**A2** **Acuminate**
L2 W1 P1 B1	**Shabala**	**Higazia**
L2 : 16 - < 18		
W1 : 3.5 - < 4.5		
P1 : 2 - < 2.5		
B1 : Lanceolate		
L3 W2 P1 B1	**Abu samaka**	**Galbeltowr**
L3 : 18 - < 20		
W2 : 4.5 - < 5.5		
P1 : 2 - < 2.5		
B1 : Lanceolate		
L3 W2 P1 B2		Mabroka
L3 : 18 - < 20		Zibda
W2 : 4.5 - < 5.5		
P1 : 2 - < 2.5		
B2 : Elliptic		

***A: apex shape**

Step (VI) Leaf texture : -

Length- Width - Petiole **Blade and Apex shape**	**T1** **Membranous**	**T2** **Chartaceus**
L3 W2 P1 B2 A2 **L3 : 18 - < 20** **W2 : 4.5 - < 5.5** **P1 : 2 - < 2.5** **B2 : Elliptic** **A2 : Acuminate**	**Mabroka**	**Zibda**

***T: texture**

4.3 Molecular diversity

The 11 Mango varieties were amplified using 4 different Operon RAPD primers. The primers were OPC9, OPL18, OPR10 and OPY14. The 4 RAPD primers used in this study were found to be polymorphic with mango cultivars tested.

All of the RAPD primers gave amplification products and they were all reproducible.

A total of 175 fragments were detected for the 11 samples representing 24 different loci with 91.7% polymorphism. Previous study using 10 primers showed that out of 76 bands, 69 bands (90.78%) were found to be polymorphic (Elgozuli, 2011). Ravishankar *et al*. (2000) reported 73% RAPD polymorphism in 18 Indian mango cultivars they studied using 10 primers. Rahman, *et al.* (2010) analysed genetic variation and relationship among 28 mango germplasm using RAPD, out of 28 primers screened, four were selected which gave 50 clear and bright fragments out of which 48 fragment were polymorphic.

The mango variety Bet bady produced only one fragment of 700 bp size with primer OPC9 ant it didn't produce any amplification product with each of the other three primers.

Variety Ras maktoul and Sinaria produced no fragment with primer OPR10 where as Bizeret Shendi and Shabala produced no fragments with OPY14 and OPL18 respectively.

The Similarity indices were calculated using Jaccard's coefficient.

The most relative varieties were Kutchineer and Taiba with 87% similarity; while the most distant were Bet bady and Wad srear with similarity percentage of 4% Table (16).

Results also indicated that the variety Bet bady has very low similarity percentages with all tested varieties (ranging from 4% with Wad srear to 9% with variety Taiba).

According to the similarity indices, the 11 samples were grouped into four clusters. Among these, variety Bet bady and variety Shabala were each grouped in separate clusters (clusters 3 and 4), varieties Bizrt shendi and Ras maktoul were grouped together in Cluster 2 while all of the other varieties were included in Cluster 1 (Fig.22).

The genetic coefficient of among mango cultivars studied ranged from 4% to 92% as shown in (table 16). Previous studies by (Elgozuli, 2011) showed that genetic coefficient ranged between 6% to 40% among 21 varieties tested.

Table (16)

Matrix of RAPD dissimilarity a mango cultivars

	Bet bady	Kutchineer	Wad srear	Higazia	Shabala	Bizrt shendi	Sinaria	Taiba	Ras maktoul	Yageen	Shreefia
Bet bady	1.00										
Kutchineer	0.05	1.00									
Wad srear	0.04	0.79	1.00								
Higazia	0.06	0.80	0.63	1.00							
Shabala	0.09	0.41	0.48	0.29	1.00						
Bizrt shendi	0.06	0.65	0.71	0.48	0.38	1.00					
Sinaria	0.07	0.67	0.58	0.72	0.30	0.43	1.00				
Taiba	0.04	0.87	0.92	0.70	0.48	0.71	0.58	1.00			
Ras maktoul	0.08	0.65	0.50	0.61	0.20	0.63	0.47	0.57	1.00		
Yageen	0.06	0.81	0.71	0.70	0.45	0.57	0.74	0.78	0.48	1.00	
Shreefia	0.06	0.76	0.67	0.65	0.47	0.52	0.68	0.67	0.43	0.75	1.00

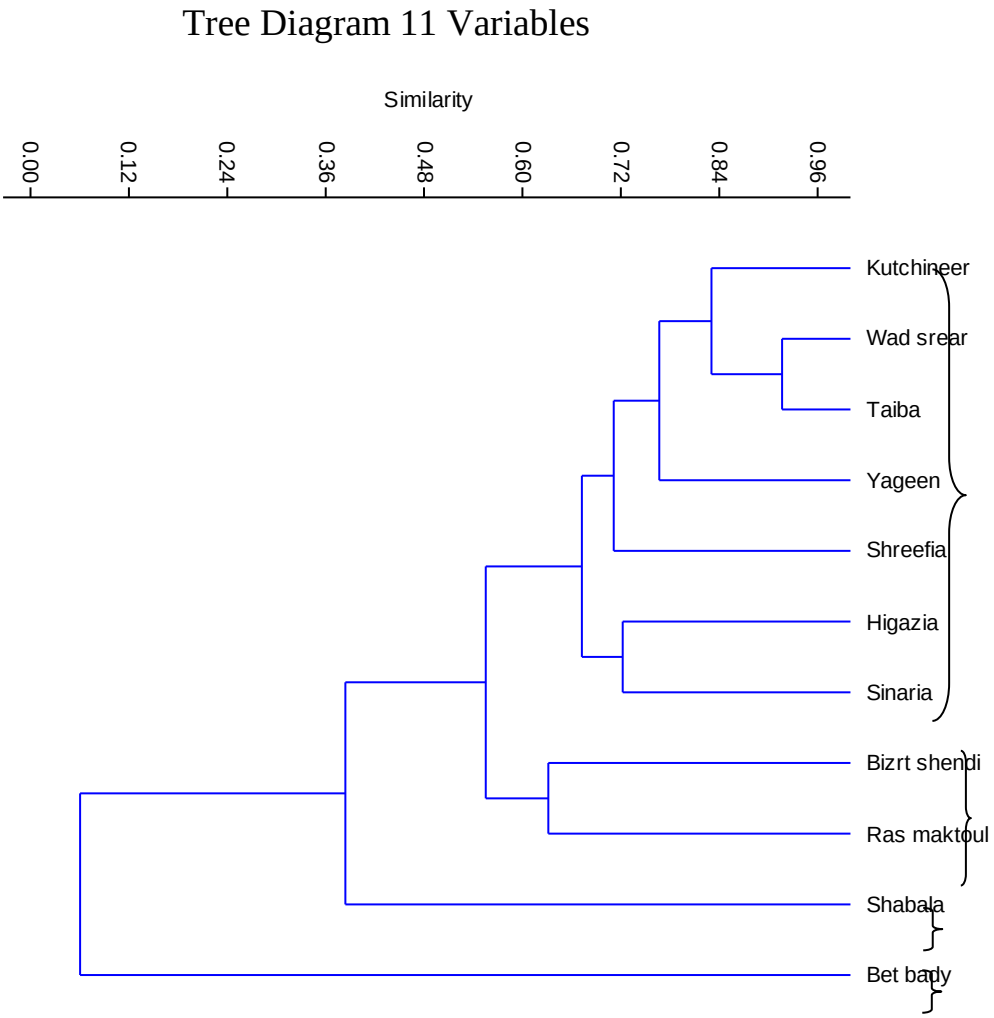


Fig22. Dendrogram based on clustering using the percentage disagreement

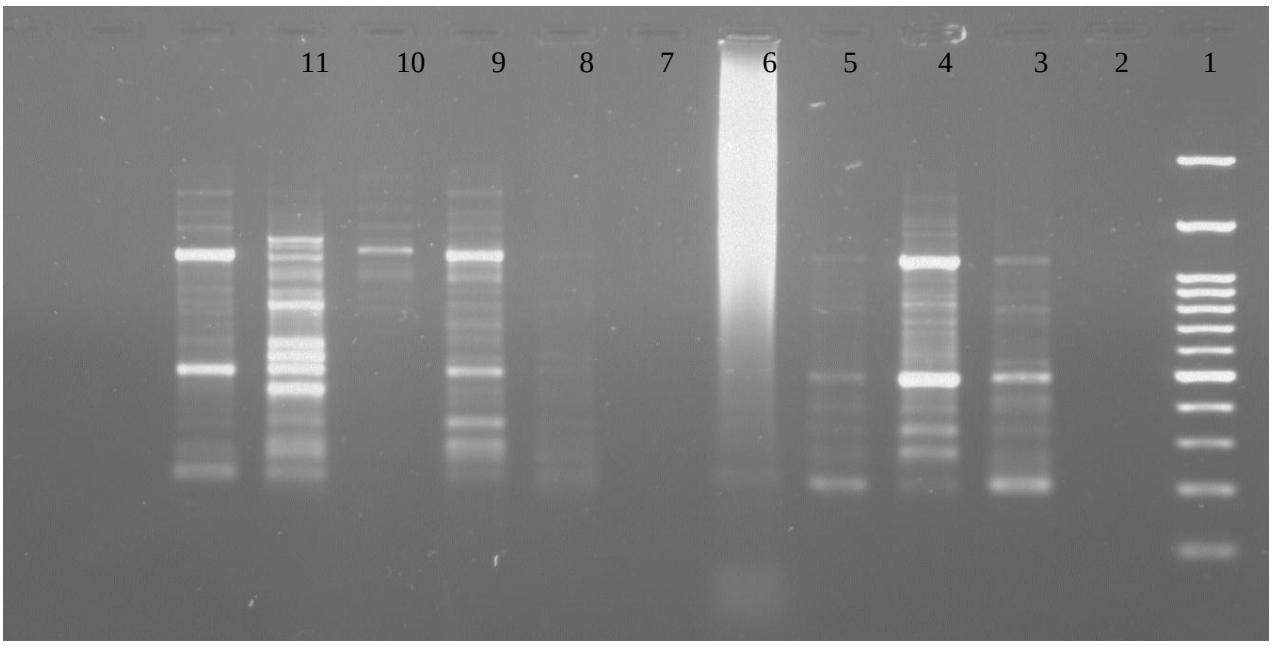


Fig23. RAPD profiles of the mango germplasm studied using primer OPY14

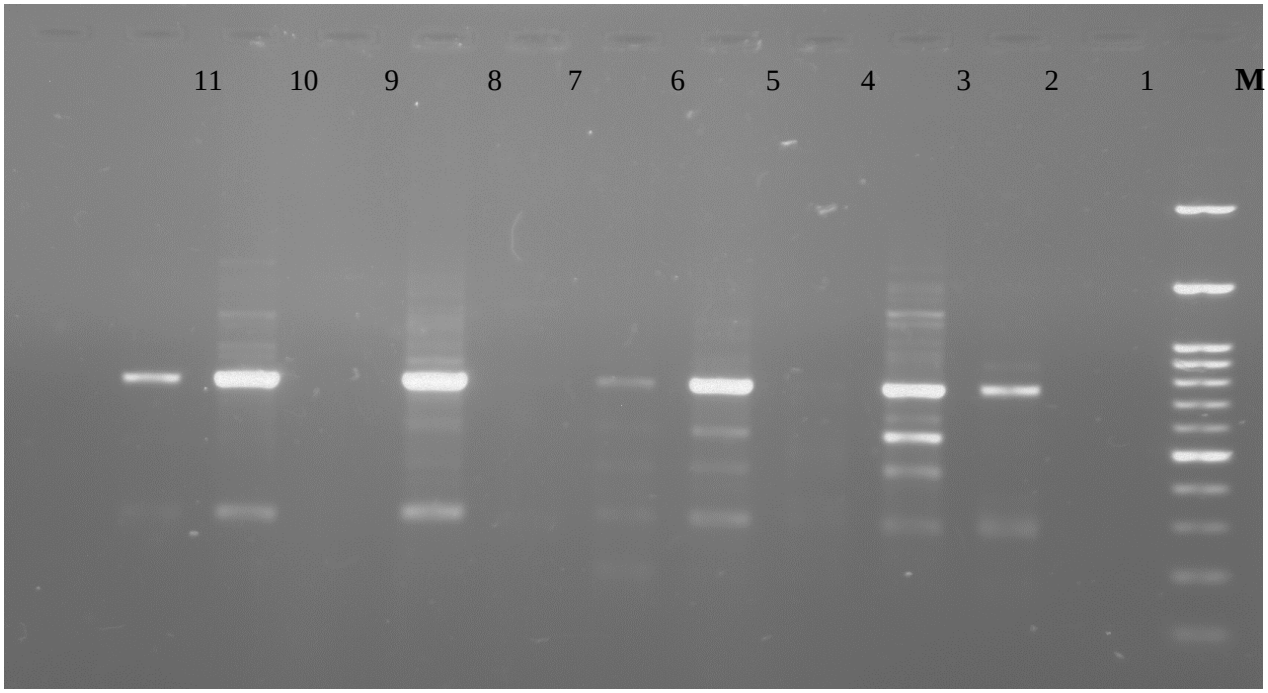


Fig24. RAPD profiles of the mango germplasm studied using primer OPR10

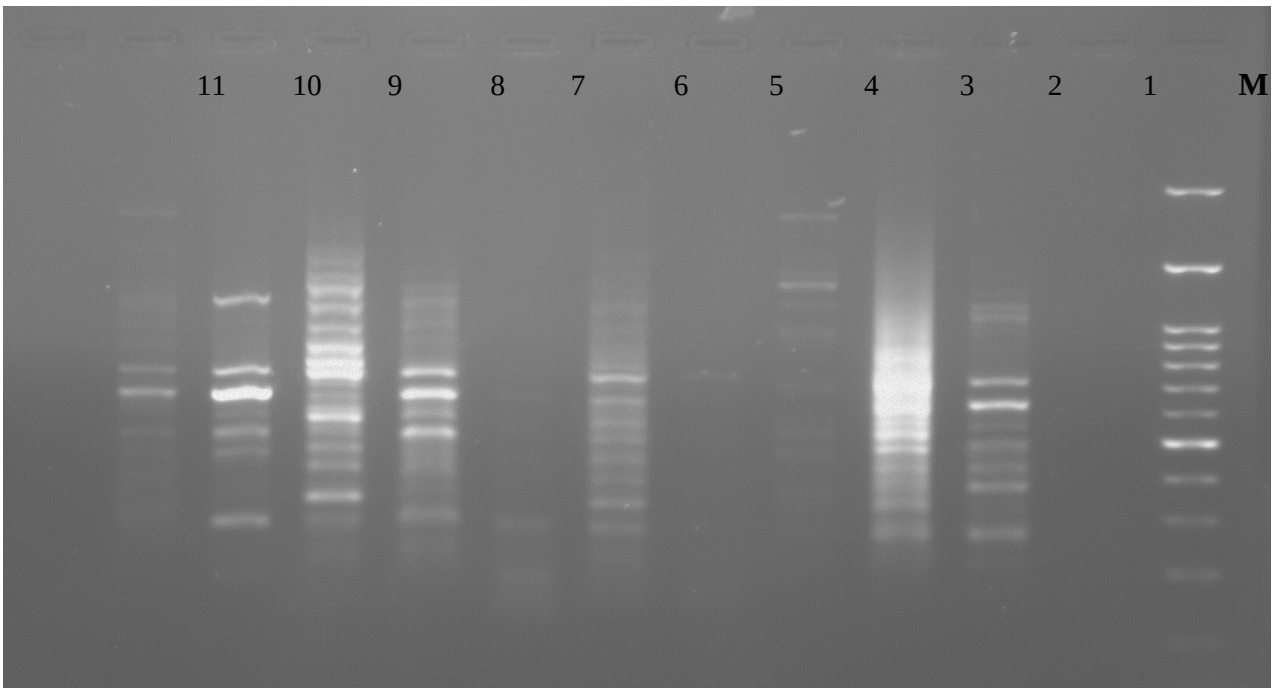


Fig25. RAPD profiles of the mango germplasm studied using primer OPL18

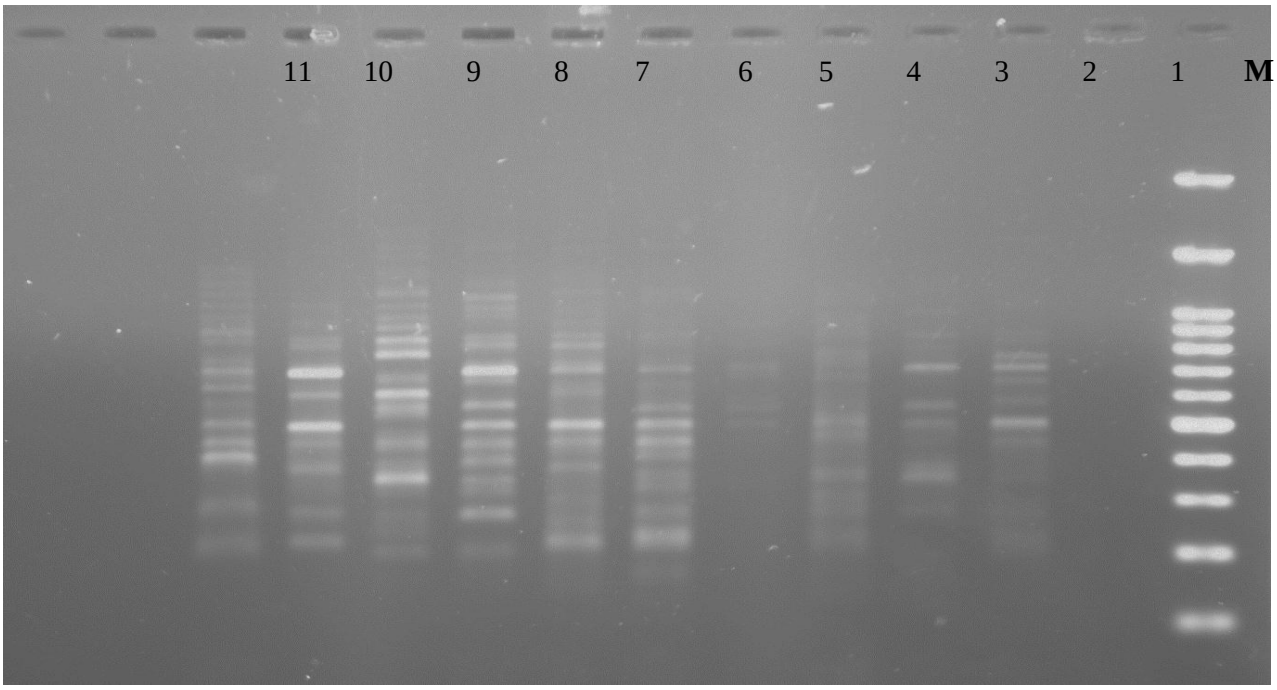


Fig26. RAPD profiles of the mango germplasm studied using primer OPC9

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APPENDIXES (1)

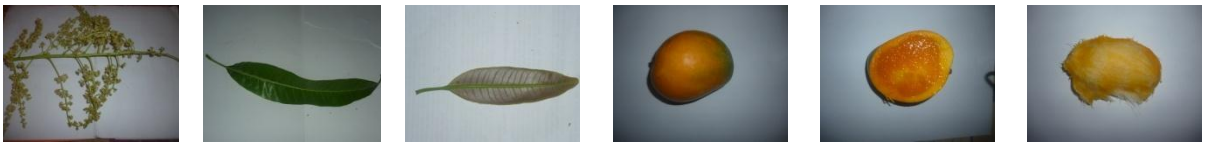
List of symbols

Segrest	**L**2
Nailum	**L**2 **W**2
Bizrt shendi	**L**2 **W**4
Wad srear	**L**3 **W**1
Malgoba	**L**4 **W**1
Sinaria	**L**4 **W**4
Taiba	**L7 W**2
Ras maktoul	**L**7 **W**4
Shendi-1	**L**2 **W**1 **P**3
Bet abusamaka	**L**3 **W**3 **P**1
Mahmoudi	**L**3 **W**3 **P**3
Mitlaky	**L**4 **W**2 **P**2
Alphonso	**L**4 **W**2 **P**4
Walibasha	**L**4 **W**3 **P**3
Timor	**L**4 **W**3 **P**5
Shreefia	**L**6 **W**2 **P**3
Dibsha	**L**6 **W**2 **P**4
Kutchineer	**L**7 **W**3 **P**3
Bet bady	**L**7 **W**3 **P**4
Yageen	**L**4 **W**2 **P**6 **B**1
Julik	**L**4 **W**2 **P**6 **B**2
Shabala	**L2 W**1 **P**1 **B**1 **A**1
Higazia	**L**2 **W**1 **P**1 **B1 A**2
Abu samaka	**L**3 **W**2 **P**1 **B1 A**1
Galbeltowr	**L**3 **W**2 **P**1 **B**1 **A**2
Mabroka	**L**3 **W**2 **P**1 **B**2 **A**2 **T**1
Zibda	**L**3 **W**2 **P**1 **B**2 **A**2 **T**2

APPENDIXES (2)

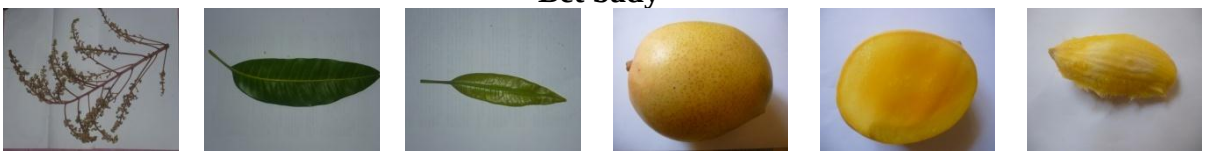
Morphological characterization

Abu samaka

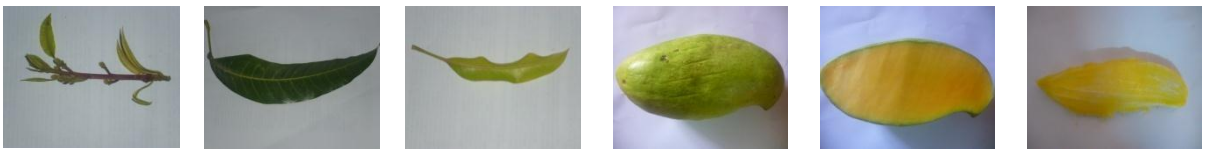


Alphonso

Bet bady



Bet abusamaka



Bizrt shendi

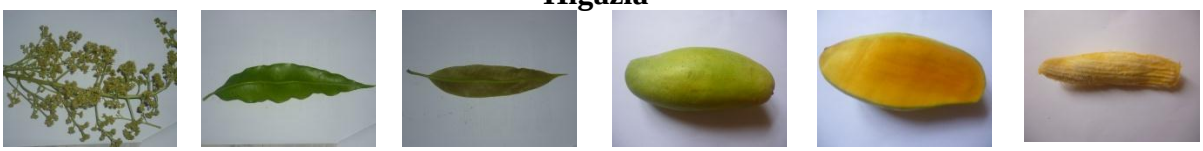
Dibsha

Elkeitt

Elken

Galpaltowr

Higazia



Julik

Kutchineer

Mabroka

Mahmoudi

Malgoba

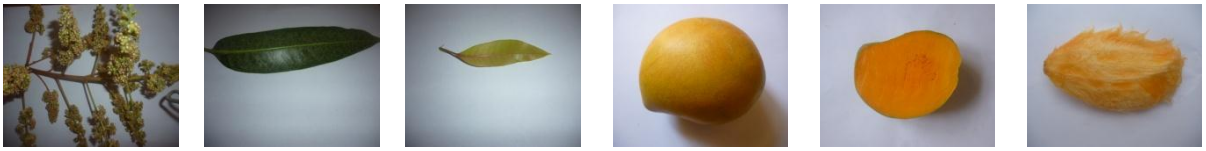
Mitlaky

Nailum

Ras maktoul

Segrest

Shabala



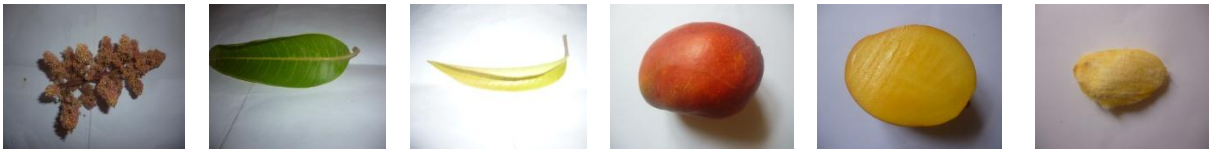
Shendi-1

Shreefia

Sinaria

Taiba

Timor

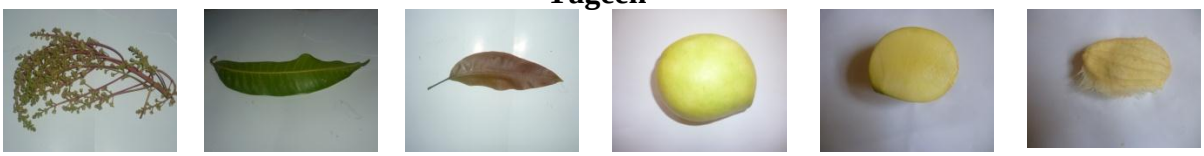


Tommy atkinz

Wad srear

Walibasha

Yageen



Zibda