Sudan University of Science and Technology

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Response of Five Onions (*Allium cepa* L.) Cultivars to Fertilizer Type and Season Reflected on Growth, Yield, Quality and Storability under Khartoum State Conditions

إستجابة خمسة أَصناف من البصل (*Allium cepa* L.) لنوع الأسمدة والموسم منعكسة على النمو، الإنتاجية، الجودة والمقدرة التخزينية تحت ظروف ولاية الخرطوم

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Dedication

To

My mother

I dedicate this research to
my dear mother, who supported me
until I reached this stage

Acknowledgments

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Abstract

Two experiments were carried out during the 2015 /16 and 2016/17 summer seasons at the Experimental Farm of Shambat Research station, Agricultural Research Corporation, Khartoum, Sudan. The purpose was to investigate the performance of five onion cultivars; Baftaim (S), Saggai lmproved, Abu-Freaiwa, Kamleen, Texas Early Yellow Grano under five fertilizers regimes (control, urea, organic, NPK and ammonium sulphate). The experimental design was in split plot with three replications. The Studies addressed three aspects which were; vegetative growth, bulb yield, quality and storability. Vegetative growth parameters used were plant height, number of leaves per plant and leaf length. Yield and quality the parameters assessed were single bulb fresh weight, total and marketable yield, doubling, bolting, bulb diameter, length, neck diameter, number of rings, total soluble solids and dry matter content. Storability evaluated using the parameters of rotting, sprouting, total bulb weight loss and diseases susceptibility (black mold infected bulbs). The results indicated that there were no significant differences among fertilizers on growth, yield and quality of onion cultivars. Whereas for cultivars both Baftaim (S) and Kamleen had ample vegetative growth while Texas Early Yellow Grano had sparse vegetative growth; however, both Baftaim (S) and Texas Early Yellow Grano were the high yielding ones. It could be explained that both have high capacities of partitioning large portions of the vegetative growth (biological yield) to the sink (bulb) which is the economic yield. Lack of cultivar and fertilizers interaction could be attributed to the cultivar genetic make-up and/or the levels and type of fertilizers used or possibly the experimental sites. All quality characters were not significantly affected by fertilizers and that could be due the fact that they are mostly genetically

controlled, however, the minor differences observed could be due the selection intensity or degree of purification attained during development of cultivars, in addition to possible cultivar – environment interactions.

Onion bulb Storability is correlated with dry matter and pungency both being genetically controlled with factors affected with management practices like harvesting, curing and the storage environment especially temperature and relative humidity. The Sudanese onion cultivars evaluated Baftaim (S), Kamleen, Saggai Improved and Abu-Freaiwa are high dry matter (≥15%) and TSS cultivars that are also pungent, consequently stored well for four months in traditional store. On the other hand the results showed that the introduced cultivar Texas Early Yellow Grano, a mild low dry matter (≤ 10%) cultivar had bad storability of 4-8 weeks under the same conditions, it recorded the highest percentage of rotted, sprouted and black mold infected bulbs.

It can be concluded that both cultivars Baftaim (S) and Kamleen showed vigor growth and gave the highest yield, quality and storability compared to other cultivars. Cultivar Texas Early Yellow Grano although showed the lowest growth and storability, gave high total and marketable yield.

المستخلص

أجريت التجربتين خلال موسمى ١٦/٢٠١٥ و ١٧/٢٠١٦ في المزرعة التجريبية بمحطة بحوث شمبات ، هيئة البحوث الزراعية ، الخرطوم ، السودان. الغرض للتتحقق من أداء خمسة أصناف من البصل هي: بافطيم (S) ، سقاى محسن ، أبو فريوة ، كاملين ، تكساس إيرلي يلو جرانو تحت خمسة آنظمة من الاسمدة (الشاهد، يوريا، سماد عضوى، NPK، سلفات الأمونيوم). كان التصميم التجريبي القطع المنشقة بثلاث مكررات. تناولت الدراسات ثلاثة جوانب هى؛ النمو الخضري، إنتاجية وجودة الأبصال والمقدرة التخزينية. تم استخدام معايير النمو الخضرى طول النبات ، عدد الأوراق للنبات الواحد وطول الورقة. بالنسبة للانتاجية والجودة المقاييس التى تم تقيمها هى الوزن الطازج للبصلة المفردة، الانتاجية الكلية والأنتاجية القابلة للتسويق ، الازدواج ،الازهار المبكر، قطر البصلة ، طولها ، قطر العنق ،عدد الاوراق الشحمية ، المواد الصلبة الذائبة الكلية ومحتوى المادة الجافة. اما المقدرة التخزينية فقد تم تقييمها بإستخدام مقاييس التعفن، التنبيت، الفقد الكلي لوزن البصل والقابلية للامراض (خاصة المصابة بالعفن الاسود).

اشارت النتائج بانه لاتوجد إختلافات معنوية بين الاسمدة فى النمو، الانتاجية والجودة لأصناف البصل. اما بالنسبه للاصناف بافطيم (S) وكاملين كلاهما كان نموه الخضرى وافر، فى حين كان تكساس ايرلى يلو جرانو شحيح النمو الخضرى؛ سجل كل من بافطيم (S) وتكساس ايرلى يلو جرانو كلاهما أعلى إنتاجية . يمكن تفسير ذلك ان كلاهما لهما قدرة تحويلية عالية لتحويل جزء كبير من النمو الخضرى (الأنتاج الحيوى) للبصلة وهو العائد الاقتصادى. إن عدم وجود تفاعل بين الأصناف والأسمدة يمكن ان يعزى الى التركيبة الجينية للاصناف و/او نوع ومستويات الأسمدة المستخدمة او ربما خواص موقع التجربة. كما لم تتاثر كل مفردات الجودة بالاسمدة.

إن المقدرة التخزينية للابصال مرتبطة بالمادة الجافة والحرافة وهى عوامل متحكم فيها وراثيا تتاثر بالعمليات الفلاحية مثل الحصاد ، المعالجة وبيئة التخزين خصوصا درجة الحرارة والرطوبة النسبية. إن أصناف البصل السودانية التى تم تقييمها : بافطيم (S) ، كاملين ، سقاى محسن و أبو فريوة عالية المادة الجافة (≤ ١٥%) والمواد الصلبة الكلية الذائبة وإيضا حريفة وبالتالى تم تخزينها جيدا لمدة أربعة اشهر فى المخزن التقليدى. من ناحية اخرى اظهرت النتائج أن الصنف الأمريكى تكساس إيرلى يلو جرانو بارد (غير حريف) منخفض المادة الجافة (≥ ١٠%) سئ المقدرة التخزينية من ٤-٨ اسابيع تحت نفس الظروف، وسجل اعلى نسبة للابصال المتعفنة، المنبتة والمصابة بالعفن الأسود.

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CHAPTER ONE

Introduction

Onion (*Allium cepa* L.) belongs to the Alliaceae family, genus Allium. The majority of the Alliums species are native to western Asia i.e. Turkestanas, Afghanistan and north of these countries (Mishu *et al*., 2013 and Farooq *et al*., 2015).

Onion is an herbaceous biennial plant and one of the oldest bulb crops (Siddiquee *et al*., 2008). Onions, leek and garlic are collectively known as alliums, as they are all species of the genus Allium, these vegetables produce organo sulphur compounds that react with the enzyme Alliinase to create the compounds which give alliums their distinctive flavors. These organo sulphur compounds are also anti-microbial and may help protect the plants from fungi and bacteria (Brown and Leclaire-Conway, 2014).

Onion is the second major important crop after tomato cultivated on large scale throughout the world. The leading onion producing countries are China, India, USA, Turkey, Iran, Pakistan, Russia, Sudan, Egypt and Brazil (FAO, 2019). According to FAO during 2019 China ranked first in onion production producing 17.588,267 tons, India stood second with production of 11.011,390 tons, USA was ranked third with a total production of 3.295,957 tons and Pakistan fourth with 2.031,870 tons. The total onion production worldwide is about 97.862 thousand metric tons in an-area of 5.201 thousand hectares of land. The world average yield is about 18.8 t/ha (FAO, 2019).

In Sudan it is ranked the first vegetable with regard to the area grown and total production. Naher El-Neil, Gezira, Northern Darfur, Khartoum and Western Darfur

States being the main producing areas. Most of the onion produced is consumed locally and only negligible of yield in Sudan is dehydrated or exported as a fresh crop to neighboring African countries and Saudi Arabia. However, onion is expected to be one of the most important exportable horticultural crops (Nourai, 2005).

The crop is consumed in the green state and as mature bulbs (Siddiquee *et al*., 2008); onions are highly valued for their flavor mainly and for their nutritional value in supplying minor constituents such as minerals and trace elements. It is widely used for various purposes in cooking, salads, preparation of soups, sauces, stew, gravies, stuffing, fried fish, ……etc (Faruq *et al*., 2003), they are also preserved in the form of pickles (Brewster, 2008), it is called the "Queen of Kitchen" onion besides being used as food is also used as medicine for the treatment of various diseases in different parts of the world (Farooq *et al*., 2015). It is successfully applied on bruises and wounds for early heal – up (Faruq *et al*., 2003).

Low yield of onion is due to improper utilization of fertilizers and growing unsuitable cultivars under the agro-climatic conditions of the area. It can be increased mainly by two ways, firstly extending the area under cultivation, and secondly increase the yield per unit area. Onion production, quality and storage are greatly influenced by the environmental factors, cultivars, agronomic factors (e.g. sowing date, nutrition, and irrigation, harvesting time), curing, handling and storage. (Nourai, 2005, Faruq *et al*., 2003 and Lee *et al*., 2016). Onion composition is variable and it is related to the environmental factors, cultivars and management practices particularly nutrients that play significant role in productivity and quality (Al-Fraihat, 2009). Onion storage is important to provide product for fresh market, export, and processing and price stability. Storage potential of onion mainly depends on the cultivar and cultural practices, climatic conditions during growing season and storage method (Chattopadhyay *et al*., 2015 and Lee *et al*., 2016). Therefore, the present study was initiated with the following objectives:

1- To investigate the performance of different cultivars for yield and quality.
2- To evaluate different types of fertilizers on onion production.
3- Reduction of the effects of some pre harvesting factors on the losses of onion bulbs during storage to extend onion bulbs shelf life.

Experiment One

Response of five onion (*Allium cepa* L.) cultivars to fertilizers types reflected on onion bulbs growth, yield and quality

CHAPTER TWO

Literature Review

2.1. Onion cultivars:

Onion cultivars bulbs varies in color (white, yellow or red), shape (flattened, round and globular to spindle or cylindrical), size (small, medium or large), and also in bulb pungency. Onions are grouped into short-days that require a above 10-12 h and long-days of 14 h or more for bulbing. A relatively high temperatures and long photoperiods are required for bulb formation (Dawar, *et al*., 2007)

Many researchers, Sekara, *et al*., (2017), Mohamedali, (2009), Brewester, (2008), Dawar, *et al*., (2007), Rabinwitch and Currah, (2002), Mohamedali, (1994) and Hassan, (1988) reported that many factors are used for characterizing onion cultivars:

2.1.1. Environmental factors:

Bulbing in onions is affected by photoperiod and temperature, onion cultivars are divided depending on the photoperiod and requirements for bulbing to three groups:

2.1.1.1. Short day cultivars:

Require 11-13 h photoperiod for bulbing, this group including all cultivars grown in Sudan such as Baftaim (S), Saggai Improved, Kamleen, Elihlo and also landraces like Abu-Freaiwa, Faddasi, Shendi Red and others.

2.1.1.2. Intermediate day cultivars:

Require 13-15 h photoperiod for bulbing like cultivar Calred and Italian Red.

2.1.1.3. Long day cultivars:

Require more than 15 h photoperiod for bulbing such as White Spanish and Yellow Sweet Spanish cultivars.

Long day and intermediate cultivars are grown in North Europe and North U.S.A. where the day length reaches 20 h in some area.

Cultivars of the same day-length vary in their bulb shape, size, skin and scale colors (white, light-yellow and dark-yellow, bronze, pink, red and dark purple) doubling, bolting, firmness, pungency, sweetness, juiciness and storage potential.

2.1.2. Physiological characters of the bulbs:

2.1.2.1. Skin and bulb color:

Onion cultivars are divided to four groups depending on scale color:

1- White bulb cultivars such as Elhilo, South Port White Globe and Crystal Wax.

2- Yellow bulb cultivars such as Kamleen and Texas Early Yellow Grano.

3- Red bulb cultivars such as Saggai Improved, Baftaim (S), Abu-Freaiwa, Faddasi and Calred.

4- Brown bulb cultivars such as Australian Brown and Dessert Brown.

2.1.2.2. Bulb shape:

About nine shapes are defined; globe, flattened globe, high globe, rounded Spanish, flat, thick flat and granex, top and spindle shape.

2.1.2.3. Bulb size:

Bulb size is related to the cultural practices mostly, relation between bulb size and dry matter percentage, cultivars with high dry matter especially dehydration cultivars such as White Creole and South port White Globe have about 18% dry matter and the bulb size ranged from medium to small bulb size. Sudanese cultivar Hudeiba Red has small bulb size and dry matter percentage more than 20%, whereas the American cultivar Texas Yellow Grano has low dry matter percentage of less than 10% but large bulb size.

2.1.3. Pungency:

Pungency is correlated with dry matter percentage and storability; the cultivars are classified according to the pungency to:

1- Low pungency (mild) cultivars like Excel, Texas Early Yellow Grano and Zalengi bulb in Sudan.

2- Medium pungency cultivars such as Yellow Tampico.

3- High pungency cultivars such as most of the Sudanese cultivars like Saggai Improved, Kamleen, Elhilo, Abu-Freaiwa, Feddasi and Red Creole.

2.1.4. Storability:

Storability is related to cultivar, harvest, and curing and storage environment. Short storability cultivars such as Texas Early Grano, intermediate storability cultivars like Excel and long storability cultivars including most of Sudanese cultivars like Saggai Improved, Kamleen, Elhilo, Abu-Freaiwa, Feddasi and Australian Brown (Mohammedali, 2009).

2.1.5. Maturity:

Onion bulb maturation varies depending on cultivars environment and season. Early maturing cultivars such as the local landrace Abu-Freaiwa and others Sudanese cultivars and late maturity cultivars like Italian Red and Torpedo.

2.2. Origin of Sudanese cultivars:

The cultivars grown in Sudan, need relatively short day (11-13 h), defined as short day cultivars in areas that are between latitudes 23^{o}- 30^{o} South and North, These areas are characterized by the length of the photo period which is slightly different or relatively constant throughout the year and therefore the length of the photoperiod is not the important factor in the formation of the bulbs. The growth and formation of the bulbs under high temperatures in the tropical regions increases the phenomenon of doubling with the increase of lateral buds and annual flowering (Mohamedali, 2009).

Accreditation of farmers to produce their own seeds led to increased genetic variability in most qualitative and quantitative qualities of Sudanese onion,

Mohamedali, 1994 and Mohamedali, 2009 reported that the origins of Sudanese cultivars are based on three main sources:

2.2.1. Onion in northern Sudan:

Resulting from hybridization among local races and Egyptian onions. They are mostly yellow or brown such as Dongola Yellow and Selaim bulbs, they are characterized by high dry matter (>15%), pungent, good storability with low early bolters and high percentages of doubling.

2.2.2. Onion in central Sudan:

Resulting from hybridization among local races and imported onions especially from USA, like Saggai, they are mostly red, high in dry matter, pungent with good storability. This group includes many local landraces named after the areas where they are grown commercially such as: Shendi Red, Wad Ramly, Khelalia, Kanour, Fadasi…… etc, but the most famous is Saggai.

2.2.3. Onion in western Sudan:

Resulting from hybridization among local races and West African onions. They are mostly yellow, white and pale red like: Zalengi, Fur onions and some known as Furawia and Darfuria. They are low in dry matter, mild, of bad storage capacities and of mixed color, shape and size.

Most of the Sudanese onions are red to reddish-brown, and some cultivars are characterized by special color (Saggai is a crimson red color- Abu- Feraiwa is dark red). They are flat to thick flat or flatted globe shape, pungent and high in dry matter percentage (15 – 18%) therefore they are suitable for traditional storage. But they have a number of quantitative and poor qualities resulting from open pollination and the wrong practice of seed production. They also lack of uniformity of color, shape and size, in addition to susceptibility to pink root rot disease and onion yellow dwarf virus (Mohamedali, 1994 and Mohamedali, 2009).

Mohamedali, (1994) reported that a breeding program was started in 1977/78 at Hudeiba Research Station, in the arid region of northern Sudan to develop distinct red cultivars for consumption, yellows for local market and fresh export and white for dehydration.

2.3. Sudanese cultivars:

2.3.1. Saggai Improved:

Released in 1987 by ARC, Variety Release Committee. Characterized by; big size, crimson red color, the bulb is multi-centered, solid, high dry in material and good storability. It needs ±142 days for full maturity (Mohamedali, 2009).

2.3.2. Kamleen:

Released in 1987 by ARC, Variety Release Committee. Characterized by; flattened globe shape, yellow skin, solid, big size, pungent and high dry matter, it needs 4 - 5 months for full maturity and higher in productivity than Saggai (Mohamedali, 2009).

2.3.3. EL-Hilo:

Released in 1987 by ARC, Variety Release Committee. Characterized by high dry matter content of about 18%, big bulbs, pungent, good storability high productivity than both Saggai Improved and Kamleen and earlier in maturity (Mohammedali, 2009).

2.3.4. Baftaim (S):

Originally introduced from Yemen and subjected to selection for adaptability in Sudan, released in 2007 by ARC, Variety Release Committee. Characterized by; big size bulbs, globe shape, solid, pungent, high in dry matter (±16%), free from the phenomena of early bolters and doubles, it's of moderate resistance to thrips, pink root rot and onion yellow dwarf virus. It needs ±153 days to mature and it is the most productive cultivar in Sudan (Mohamedali, 2007, 2009).

2.3.5. Abu- Freaiwa:

Local cultivar (land variety), in the last ten years it spread in the Sudan for its traits particular early maturing, high dry matter percentage (±24%), pungent, good storability under open storage facilities. The bulbs are red dark to red, flatted globe to thick flat shape, solid with high percentages of doubles and bolters and low yield compared to other released cultivars. It highly tolerant to stresses such as drought and weeds competition (Mohamedali, 2009 and 2007).

2.4. Plant characters of onion cultivars:

Dawar *et al.*, (2007) found that onion cultivars differ significantly with respect to number of leaves; ranging 15.2 to 12.8 (Gilassi local and Swat-1 cultivars).

Onion cultivars differ significantly in plant growth characters as expressed by plant height and number of leaves, Geries *et al.*, 2012 reported that cultivar Gize Red had the highest value than cultivar Giza 20, also Mousa (2015) recorded that cultivar Red Amposta significantly produced the tallest plants, highest number of leaves/plant, while the shortest plants and least number of leaves /plant were produced by the onion cultivar Gize 6.

The effect of cultivars in leaf length was highly significant, of maximum (48.00cm) and minimum (41.02cm) as recorded in Phulkara and Faisalabad Early, respectively (Dawar *et al.,* 2007), also Ghaffoor *et al.,* (2003), confirmed that leaf length varied significantly among onion cultivars.

In Sudan many researchers tested local and introduced onion cultivars. Eltayeb (2006) reported that six local onion cultivars namely, Saggai Improved, Kamleen, Elhilo, Abu-Feraiwa, Wad Hamid and Zeidab, varied considerably in their growth habits including the number of leaves/plant and plant height, whereas Idriss, (2007) found differences among some local and introduced cultivars in number of leaves and leaf length. Baftaim Improved -1 recorded the highest number of leaves (12) while the other local cultivars, Saggai Improved, Kamleen and Abu-Feraiwa (10, 11 and11 respectively). Baftaim Improved -1 varied significantly in leaf length, it recorded the tallest leaves (58 cm) compared to Saggai Improved, Kamleen and Abu-Feraiwa that recorded 50, 53 and 53cm respectively.

2.5. Onion cultivars yield and yield components:

Many researchers evaluated different cultivars (local and introduced) with respect to total yield, marketable yield, doubles and early bolted bulbs, cultivars differed in total yield, marketable yield and culls (doubles and bolters), in yield capacity, the highest value obtained by cultivar Giza Red compared to cultivar Giza 20 (Geries *et al*., 2012).

Significant differences were observed among three cultivars in total bulb yield, cultivar Bombay Red was the highest in total and marketable bulb yield than Adama Red and Nasik Red. Adama Red and Nasik red were statistically identical in total and marketable yield (Benti, 2017).

Kimani *et al*., (1993) found that bulb yield varied among cultivars, the introduced cultivars did not better than the local ones, and KON3 was the best among the recently introduced cultivars, while Tropicana was the best among the local cultivars. Generally some of the introduced cultivars have considerable potential for local growers; and out yielded the local ones.

Pakyurek *et al.*, (1994) tested various cultivars for yield and quality and concluded that not all cultivars gave similar response. Similarly, Rumpel and Felezynski (1997), Singh and Sachan (1999), Rumpel *et al*., (2000) and Vanparys,(1999) found that onion cultivars varied significantly in yield and quality.

Dawar *et al*., (2007), found that yield differed markedly among the onion cultivars, cultivar Terich-02 gave (7.1 t/ha), whereas cultivar Gilassi local recorded (4.8 t/ha). The same cultivars depicted non significant impact over the weight of double bulbs. Results indicated marked variation between two cultivars in commercial yield (large- medium bulb), cultivar Terich-02 recorded maximum weight of large and medium size bulbs, while cultivar Gilassi local recoded the minimum weight of the two sizes.

Jilani *et al*., (2004) found significant variations among three onion cultivars with respect to yield, highest yield (15.79 t/ha) was recorded with Shah Alam cultivar and the lowest yield (13.45 t/ha) was recorded for Phulkara, same result was reported by Abbes *et al*., (1995), whereas, the effect of cultivars on marketable yield was not significant. The effect of cultivars on double bulbs percentage was highly significant, maximum double percentage (22%) was recorded by Phulkara followed by Faisalabad Early and Shah Alam with 20 and 17%, respectively. Marketable bulb yield was significantly affected by cultivars, the mean of marketable yield of 16.6 and 7.3 t/ha was reported for cultivars N-53 and Red Creole, respectively (Gautam *et al*., 2006).

Mousa (2015), reported significant variation in marketable yield among tested cultivars, Texas 502 gave the highest marketable yield (20.2 t/ha), whereas Giza 6 recorded the least marketable yield (8.4 t/ha). Marked variation in un- marketable yield, the cultivar Red Amposta produced the highest yield of doubling and early bolting 21.3 and 4.3 t/ha respectively, and the least yields of doubling and early bolting were produced by the cultivar Texas 502.

Sudanese onion cultivars and introduced cultivars were evaluated by many researchers targeting high yield and quality of the crop. Mohammedali, 2007 tested introduced genotypes from Yemen; Baftaim Improved -1, and Baftaim Improved 2, Baftaim Yellow and the released cultivars Saggai Improved, Kamleen and Elhilo. He reported that the superiorly of Baftaim Improved -1 over Saggai Improved. Also Ali *et al*., 2011 reported significant differences between two tested cultivars; Baftaim(S) produced the higher total bulb yield (20.3 t/ha) than Abu-Freaiwa (12.5 t/ha). Whereas for bolting and doubling percentages, cultivar Baftaim (S) gave less than 2 and 1% of doubling and bolting, respectively compared to Abu-Freaiwa which gave about 45 % in both doubling and bolting percentage.

With respect to marketable yield, there was significantly variations among onion cultivars, Baftaim Improved-1, reported the highest marketable yield (51.97 t/ha) and Saggai Improved, Kamleen and Abu-Freaiwa gave 33.32, 32.71 and 31.79 t/ha respectively. Marked variations were found among local and introduced cultivars in double and bolting percentages, Abu-Freaiwa recorded the highest the percentage in both (14 and 7%), while the introduced Baftaim Improved-1(6 and 4) in both parameters respectively. The other local cultivars recorded 4% in both parameters Idriss, (2007) and Eltyeb, (2006), reported significant differences in total yield among the local tested cultivars. Kamleen gave the highest total yield (22.9 t/ha) followed by Wad-Hamid (20.8 t/ha), Elhilo (19.7 t/ha), Saggai Improved (19.2 t/ha), Zeidab (16.2 t/ha) and Abu-Freaiwa was the lowest in total yield (14.6 t/ha), also the same local cultivars differed significantly in marketable yield, cultivar Kamleen recorded the highest marketable yield of 14.5 t/ha followed by Elhilo, Saggai Improved, Abu-Freaiwa, Wad-Hamid and Zeidab (13.3, 10.4, 8.6, 7.6 and 6.5 t/ha respectively). Local onion cultivars varied significantly in double percentages, it ranged from 14.46 to 8.84%. The highest double percentage was recorded in Wad-Hamid and Kamleen reported the lowest double percentage. Premature bolting ranged from 12.46 to 7.73% obtained by Zeidab and Kamleen, respectively (Eltayeb, 2006).

2.6. Onion bulbs quality:

Onion bulb quality differs among cultivars, physical and chemical characters are measured to evaluate bulb quality, important characters are bulb average weight (g), bulb diameter (cm), bulb length (cm), bulb neck diameter (cm), number of storage leaves (number of rings), total soluble solids (TSS) and bulb dry matter content.

Many researcher studied onion bulb quality, Dawar *et al*., (2007), reported that maximum weight of single bulb obtained by cultivars Terich-02 and Swat -1 was 1.5 and 1.4 kg respectively, while the minimum was recorded in cultivar Gilassi local (0.1 kg). Bulb weight varied significantly, the newly introduced cultivars had higher bulb weight than the local ones. Cultivar KON3 had the largest bulbs and

Bombay Red the smallest bulbs. Kimani *et al*., (1993), and also Mousa (2015) found that the onion cultivar Red Amposta produced bulbs with highest weight and diameters, whereas Giza 6 recorded the smallest weight and diameters of the bulbs

Onion cultivars differ significantly in the average bulb weight and bulb diameter. Cultivar Giza Red reported the highest average bulb weight and bulb diameter while the highest TSS and dry matter content were reported for Giza 209 (Geries *et al*., 2012)

Four tested cultivars showed no significant differences in the neck diameter and bulb length, while, there were significant differences in diameter of bulb among tested cultivars (Gautam *et al*., 2006).

Kimani *et al*., (1993) reported that dry matter content varied significantly among local and new introduced cultivars. Dry matter content was higher in local cultivars (8.4-12.4%) than the exotics cultivars (3.4-10.60 %).

Onion bulbs with high dry matter tend to yield less than those with low dry matter content, the latter also exhibit rapid bulbing. Also they noted that onion bulbs with high dry matter are firmer and hence more resistant to damage and storage, and have thicker, well adhering skins which retain water better than thin skins (Currah and Preoctor, 1990)

Dry matter in onion bulbs varies from low levels (7-10%) to high levels (15-20%). Onion with high dry matter (≥20%) is preferred for processing (Kimani, *et al*., 1993).

Some Sudanese studies in bulb quality, indicated that Baftaim (S) has higher bulb diameter (3-3.6 cm), bulb weight (187g) and dry matter content of 16.53% Abu-Freaiwa has a lower bulb diameter, bulb weight and dry matter content(6.73cm, 150.9g and 15.9%, respectively) (Ali *et al*., 2010). Eltyeb, (2006) reported that cultivar Kamleen produced heavier bulbs (144.6 g) while cultivar Zaidab gave 101.6 g. Bulb diameter of some cultivars ranged from 5.71cm recorded by Kamleen to 5.14cm reported by Zeidab. The bulb length ranged from 5.93cm for Wad-Hamid to 5.38 cm recorded by Zeidab cultivar. Significant variations were recorded in total soluble solids among some of local cultivars, Kamleen and Elhilo recorded 17.33%and 17.32%, followed by Abu-Freaiwa, Saggai Improved and Zeidab (15.46%, 15.39% and 14.9%, respectively). The lowest total soluble solid of 14.67% was recorded for Wad-Hamid. Dry matter content differed significantly among the local onion cultivars, Kamleen recorded 16.07% followed by Saggai Improved, Elhilo, Wad-Hamid and Abu-Feraiwa (15.01%, 14.83%, 14.64% and 14.62%, respectively) while cultivar Zeidab with the lowest dry matter content.

Significant differences were reported for bulb fresh weight; Baftaim Improved -1 recorded the heaviest bulb (107 g) while the local cultivars, Saggai Improved, Kamleen and Abu-Feraiwa recorded 76, 84 and 79 g, respectively. Dry matter percentages varied significantly among local and introduced cultivars, the highest dry matter was recorded by Abu-Freaiwa (24%) while Baftaim Improved -1 recorded 18%, Kamleen and Saggai improved 14% (Idriss, 2007).

2.2. Fertilizer:

The major plant nutrients; nitrogen, phosphorus, potassium, sulphur, magnesium and calcium play vital roles influencing bulb yield and yield attributing characters as well as the shelf life of the onions.

Onion is more susceptible to nutrient deficiencies than most crop plants because of its shallow and un-branched root system. However, its response depends on fertilizer type (Brewester, 2008 and Dapaah *et al*., 2014). Moreover, it is preferable to split fertilizer application (before sowing or planting, at the fully expanded leaf stage, and just before bulb formation). High nutrient availability is important during bulb formation (Malik, 1994).

Fertilizer management is one of the important factors that may contribute much to the onion yield and quality (Bose and Som, 1986; Vachhani and Patel, 1993). Balanced fertilizer application is essential for the vegetative growth and, thus, for producing crops with top quality and high yields especially on soils that are cultivated continuously (Chintala *et al*., 2012a; 2012b). The amount to be applied depends on the type and fertility status of the soil; however, it requires identification of optimum fertilizer dose organic or inorganic. (Yohannas *et al.*, 2013).

Farmers usually depend upon on organic fertilizers to improve onion yield while modern agricultural practices encourage the use of inorganic fertilizers to boost the crop yield. Organic material like farmyard manure (FYM) enhances plant growth, development and ultimately yields, because it improves the soil physical, chemical and biological properties along-with the provision of macro and micro nutrients.

Nitrogen, potassium and sulphur are the important nutrient elements that play important roles in bulb formation, elongation, skin color development and pungency of onion (Bose and Som, 1986; Vachhani and Patel, 1993).

Integrated nutrient management is a vital strategy for promoting efficient use of chemical fertilizers in combination with organic manure (Yohannas *et al.,* 2013).

2.2.1. Organic fertilizer:

Application of chemical fertilizers alone generates several deleterious effects on the environment and human health; they should be replenished every season because they are rapidly lost either by evaporation or by leaching in drainage water causing dangerous environmental pollution (Aisha *et al.*, 2007), While organic manures improve these properties (Watson *et al*., 2002).

In addition, continuous usages of chemical (inorganic) fertilizers affect soil structure and fauna. Hence organic manure can serve as an alternative to mineral fertilizers (Naeem *et al*., 2009 and Abdel Naby *et al*., 2012).

Judicious use of organic manures can maintain long term soil fertility and sustain higher productivity of crops. (Al-Fraihat, 2009).

2.2.1.1. Effect of organic fertilizer on vegetative growth:

Mousa and Mohamed (2009), Dapaah *et al*., (2014) and Shedeed *et al*., (2014), stated that different types of organic fertilizers increased the onion vegetative growth parameters (plant height, leaf length, bulb diameter and fresh weight), in addition to the uptake of N, P, K, Ca and Mg. Kwada *et al*., (2015), reported that application of 5.5 t/ha of poultry manure gave the tallest plants. Similar results were reported by Reddy and Reddy (2005) and Bagali *et al*., (2012), showed that the application of different types of organic fertilizer (vermicompost at 6 t/ha, poultry manure at 3t/ha and farmyard manure at 30 t/ha), had similar significant effects on plant growth giving the highest plants and the tallest number of leaves/plant.

Application of 15- 20 t/ha of poultry manure produced the highest number of leaves per plant than NPK and control. Kandil *et al*., (2013) reported that the lowest plant height and number of leaves were recorded by the application of 35 t/ha organic manure. However, Reddy and Reddy (2005) observed that the tallest plants of onion were obtained with the highest combination of vermicompost (30 t/ha) and nitrogen (200 kg/ha) compared to the lowest dose (10 t/ha and 50 kg/ha).

2.2.1.2. Effect of organic fertilizer on yield and quality:

Addition of farmyard manures 15-20 t/ha gave the highest onion yield (Abdelrazzag, 2002, Eldardiry *et al.*, 2015 and Kwada *et al*., 2015). However, Aisha *et al*., (2007) and Kandil *et al*., (2013) reported that the lowest onion yield and quality (total soluble solids and dry matter) were obtained with the addition of the lowest (4 t/ha) or the highest (35 t/ha) dose of farmyard manure. Nevertheless, Abdel Naby *et al.*, (2012) reported no significant positive effects on bulbs fresh weight diameter and total yield compared to other organic fertilizers or NPK.

2.2.2. Nitrogen:

Nitrogen is the principal plant nutrient required in large quantities. It is an important component of proteins, enzymes and vitamins in plants and it is the central part of essential photosynthetic molecules and chlorophyll. Moreover, it is an important component of most metabolic processes. (Marschner, 1995). Onion is a heavy feeder, requiring ample supplies of N; hence it requires and often responds well to addition of fertilizers. However, excess application of nitrogen causes excessive vegetative growth, delayed maturity, increase susceptibility to diseases, reduces dry matter contents, storability and ultimately reduces yield and quality of the bulbs (Brewster, 2008; Sørensen and Grevsen, 2001).

2.2.2.1. Effect of nitrogen fertilizers on vegetative growth:

Many researches (Kumar *et al*., 2001, Lemma and Shimelis (2003), Khan *et al.*, 2007, Dina *et al*., 2010 and Abdissa *et al*., 2011), studied optimum dose of nitrogen to give optimum plant growth and yield. Their recommendations, however, varied widely. Nasreen *et al.,* (2007), found that addition of 120 kg N/ha increased significantly the number of leaves/plant and plant height compared to the control. Islam *et al.*, (1999), stated that addition of nitrogen up to 180 kg N/ha gave the tallest plants and the highest number of leaves/plant.

Yaso *et al*., (2007) and Moradi (2015), revealed that increasing mineral nitrogen levels (214 kg N or 300 kg urea/ha) led to significant increases in plant height and number of leaves. However, Abdissa *et al*., (2011), stated that the application of 69- 92 kg N/ha increased significantly the number of leaves/plant, leaf length and plant height. Kumar *et al*., (2001), stated that the highest doses of nitrogen up to 130 kg/ha gave the highest number of green leaves.

Application of N fertilizer gave highly significant influence on plant height of onion, addition of 50 kg/ha brought about 10.48% compared to the control, it could be attributed to the fact that N is one of the important building blocks of amino acids. Similarly, significantly influenced the number of leaves, that increased by about 8.59% in response to application of 50 kg/ha over the control and gave highly significant increase in leaves length by 5.82%. (Messele, 2016).

2.2.2.2. Effect of nitrogen fertilizer on yield and quality:

The increase of vegetative growth due to nitrogen application (120 up to 150 kg urea/ha or 120 kg N/ha) was reflected on onion yield (bulb size and weight) as stated by Moradi (2015) and Nasreen *et al*., (2007). Moreover, Tsegaye *et al.*, (2016), showed that the lowest nitrogen dose (100 kg/ha) gave the highest marketable and total yield of onion compared to the highest doses (150 – 200 kg N/ha). Similar results were also obtained by Islam *et al.,* (1999), showing that the largest bulbs and the highest yield were obtained at 120 kg N/ha compared to 180 kg N/ha.

However, Moursy *et al*., (2007), found that addition of a higher nitrogen dose (190 kg N/ha) gave significant increases in onion yield and quality (bulb diameter and total soluble solids) compared to the lower rate (95 kg/ha).

Many researchers (Soleymani and Shahrajabian, 2012, Yaso *et al*., 2007, Abdissa, 2011 and Romamoorthy *et al*., 2000) reported that higher doses of nitrogen up to 214 kg N/ha increased both onion yield (bulb weight) and quality (marketable yield, bulb diameter, dry matter and total soluble solids). Yohannas *et al.* (2013), reported that the maximum rate of nitrogen (150 kg/ha) increased bulb length compared to control.

Brewester (1987) reported that the neck-thickness is a physiological disorder that is influenced by season, site and cultivars. However, Jilani *et al*., (2004) reported that neck-thickness of onion bulb was due to high nitrogen dose (200 kg N/ha). Fatideh and Asil (2012) reported that using nitrogen at 150 kg/ha reduced the bulb weight and recorded higher bulb dry matter. Whereas, Moradi (2015) found that application of 300 and 1500kg/ha urea increased fresh weight, bulb size, bulb diameter and nitrate concentration compared to control. Moreover, Tsegaye *et al.*, (2016) reported that increasing nitrogen and irrigation frequency increased bulb size.

Jilani *et al*., (2004) reported that application of N at 200 kg / ha enhanced the number of thick-necked bulbs and highly significant increased bulb diameter without affecting bulb length.

Application of N at a rate of 50 kg/ ha increased the total and marketable bulb yields by about 46.2 and 60.4%, respectively and also increased bulb diameter by about 19.81% and the average bulb weight by 46.2% compared to the control. Moreover, length and diameter of bulb, single weight significantly increased with the increase of nitrogen fertilizer up to 150 kg N/ha (Messele, 2016). Nitrogen comprises 7% of total dry matter of the plants and is a constituent of may fundamental cell components (Bungard *et al*., 1999).

Soleymani and Shahrajabian (2012) showed that the highest and the lowest marketable yield were obtained with the application of 300 kg N/ ha and 400 kg N ha, respectively. Negash *et al*., (2009) also reported that increasing the rate of N fertilization from 0 to 138 kg/ ha increased total bulb yield from 19.26 t/ ha to 32.24 t/ ha. Similarly, increasing the rate of nitrogen application from 0 to 138 kg /ha significantly increased marketable bulb yield from 18.82 t/ ha to 31.90 t/ ha which is 69.5% higher than the control. Jilani *et al*., (2004) reported that with increase in dose of nitrogen up to120 kg N/ ha, the marketable and total bulb yields were increased, but below this level the total yield t/ ha began to decrease.

A significant increase in total bulb yield in response to nitrogen fertilizer levels was also observed by (Balemi *et al*., 2007).

Abbes *et al*., (1995), indicated that onions grow better when supplied with ammonium rather than N at the seedling stage. It was concluded that the number of days was increased to maturity by increasing nitrogen rate.

2.2.3. Combination of nitrogen, phosphorus and potassium (NPK):

2.2.3.1. Effect of combination of nitrogen, phosphorus and potassium (NPK) on vegetative growth:

The positive significant effects of balanced NPK fertilizer on growth of many vegetables compared to a single dose of nitrogen, phosphorus or potassium were reported by many researchers. Abdel Naby *et al.*, (2012), found that a balanced combination of NPK fertilizer gave the highest value of plant height. Moreover, many investigators (Bagali *et al*., 2012, Kandil, *et al*. 2013 and Shedeed *et al.*, 2014) reported that the NPK combination of 162-214 kg N/ha, 32-71 kg P/ha and 57-148 kg K/ha, respectively, increased onion vegetative growth (plant height and number of leaves /plant) compared to their application as single doses.

Application of NPK (15:15:15) at the rate (0, 120 and 240 kg NPK/ha), showed that there were no significant differences among the fertilizer levels in growth (Elhag 2012).

2.2.3.2. Effect of combination of nitrogen, phosphorus and potassium (NPK) on yield and quality:

Yoldas *et al*., (2011) showed that the recommended dose (120:100:150 NPK), influenced significantly bulb width, number of storage leaves, bulb yield, bulb weight and height. Many researchers, Bagali *et al*., (2012), Kandil *et al*., (2013) and Kadiri *et al*., (2015), reported high onion yield (bulb weight) and quality (increased marketable yield, total soluble solids and dry matter) due to high combination of NPK(81-214 kg N/ha, 16-71 kg P/ha and 57-148 Kg K/ha) compared to single doses of them. Rahman (2006), reported high bulbs dry matter with a combination of NPK alone or with organic fertilizer.

Elhag (2012), reported that the use of NPK (15:15:15) at the rate (0, 120 and 240 kg NPK/ha), reflected no significant differences among the fertilizer levels in yield, quality and storage parameters.

2.2.4. Sulphur:

Sulphur is recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium in crops. (Anwar *et al*., 2001 and Forney *et al.*, 2010). Onion is sulphur-loving crop (Kumar and Singh, 1995).

Sulphur is a constituent of secondary compounds viz., allin, cycloallin and thiopropanol and related to taste, pungency and medicinal properties of onion besides inducing resistance against pests and diseases. Sulphur is also required for the synthesis of three important essential amino acid, cystine (27%S) cysteine (26%S) and methionine (21%S) besides increasing allyl propyl disulphide alkaloid (43%S) and the capsaicin, the principle alkaloid responsible for pungency in onion and chilli, respectively (Bloem *et al*., 2004, Randle and Bussard, 1993 and Haris, 2016). These amino acids are building blocks for essential proteins in the plant. Moreover, it is essential and required for good vegetative growth, bulb development in the onion and has a strong effect on flavor and pungency through involvement in the volatile S-compounds (Anwar *et al*., 2001 and Forney *et al.*, 2010)

Sulphur application as a soil amendment, increases fertilizer efficiency, and availability of nutrients, it has several effects such as reducing pH, improving the soil water relation (Marschner, 1995 and Bloem *et al*., 2004) and the availability of microelements such as Fe, Zn, Mn, and cu beside improving the chemical properties of alkaline soil and so improving productivity of yield and its related characteristics. Application of sulphur at the rate 45 kg S/ha, significantly increased the uptake of N, P, K and S by onion plants (Sankaran *et al*., 2005), also Dabhi *et al*. (2004), reported that higher content and uptake of P, K, Mg, S, Zn and Cu in onion bulb were observed with 30 kg S/ha followed by 20 kg S/ha.

2.2.4.1. Effect of sulphur on vegetative growth:

The highest plant length and number of green leaves was obtained by using suphur (Dabhi *et al*., 2004; Jaggi, 2005; Nasreen and Imamul Huq, 2005 and Nasreen *et al*., 2007).

Application of sulphur at a rate of 400 kg S/fed markedly enhanced vegetative growth, Rizk *et al*, (2012) and Sharma *et al*., (2002), found that a linear increment of plant growth, plant height and number of leaves/plant were significantly increased with increased application of sulphur up to 36 kg S/ha. Jana and kabir (1992), indicated that highest plant length and number of green leaves were obtained at 30 kg/ha of sulphur, similar trend was obtained by Sharma *et al.*, (2002), who found a linear increment of plant growth with sulphur application rate from 15 to 60 kg S/ha. Haris *et al.*, (2016) reported that addition of 45 kg S/ ha gave the maximum plant height and number of leaves per plant at 30, 60 and 90 days after planting.

2.2.4.2. Effect of sulphur on yield and quality:

Onion bulbs yield was increased by the increments of the sulphur rate application (Attia, 2001 and El-shafie and El-Gamaily, 2002), it has also improved bulb quality especially flavor and pungency (Jaggi and Dixit, 1999). Sulphur supply influenced bulb yield, plant dry matter, bulb pungency and flavor intensity (Sharma *et al*., 2002).

Significantly high total yield and marketable yield were obtained with the application of sulphur at 30kg ha. Singh, (2008), reported that the application of sulphur as sulphur 95 or gypsum up to 40 kg/ha significantly increased bulb yield of onion and garlic plants. Afterwards, the yield was reduced at higher levels of 60 kg/ha. The highest bulb diameter, weight of bulbs and yield were obtained by using sulphur (Dabhi *et al*., 2004; Jaggi, 2005; Nasreen and Imamul Huq, 2005 and Nasreen *et al*., 2007). Jana and kabir (1992) indicated that the highest bulb diameter, weight of 10 bulbs and yield were obtained at 30 kg/ha of sulphur. Similar trend was obtained by Sharma *et al*., (2002) who found a linear increment of plant growth, bulb diameter end yield with sulphur application rate from

15 to 60 kg S/ha. Lancaster and Rnadle (2002), reported that the application of sulphur up to 36 kg S/ha significantly increased length and diameter of bulb, single bulb weight and yield. Application of 480 kg/ ha and 240 kg S/ha recorded the highest value of bulbing ratio as a result of increased bulb diameter (El-Tantawy and El-Beik, 2009). Application of sulphur at a rate of 960 kg S/ha markedly enhanced all measured parameters recording the highest values of the average weight of harvested bulb and bulb yield (Rizk *et al.*, 2012). Addition of 45 kg S/ ha recorded maximum neck thickness, diameter of bulb, number of rings per bulb, average bulb dry weight, total bulb yield and marketable bulb yield (Haris *et al.*, 2016).

CHAPTER THREE

Materials and Methods

3.1. Field Experiment:

3.1.1. Location:

The field experiments were carried out during two consecutive summer seasons of the 2015 /16 and 2016/17 at the Experimental Farm of Shambat Research Station, Agricultural Research Corporation , Sudan , Khartoum North (Lat. 15° ٤٠’’ N and long . 32° 32’ E . and 281m.above sea level).

The physical and chemical properties of the soils are presented in Annex 1.

The mean maximum and minimum temperatures were 36.3 and 19.5c° respectively during the growing season, average relative humidity r of 26.8%, and average rainfall of 1.0 mm / annum in the first season, while in the second season the mean maximum and minimum were of 37.1 and 20.6 c° respectively during the growing season, average relative humidity of 26.4%, and average rainfall 6.8 mm / annum (Annex 2).

3.1.2. Planting materials

The seeds of five onion cultivars were sown in the nursery on 60 cm ridges at the 15 g / m^2 seed rate, fertilized by urea (4.7g/m^2) after 21 days, hand weeded once time and transplanted when 6-7 weeks old.

The five onion cultivars were:

1-Baftaim (S) (red)

2-Saggai lmproved (red),

3- Abu-Freaiwa (dark red)

4- Kamleen (yellow).

5- Texas Early Yellow Grano (yellow).

3.1.3. Treatments:

The experiment included 25 treatments combinations of 5 cultivars×5 fertilizers (Annex 4).

The fertilizers used were:

1- Control (without fertilizer).

2- Urea (46%N):

93.5 Kg/ feddan (224.4 Kg/ ha), splitted in two equal doses one month from transplanting and second after one month from the first dose.

3- Organic (Elshmokh (Annex 3).

The organic manure 6.25 t/ feddan (15 t/ ha), was added after the soil was ploughing, leveling and ridging.

4- NPK (15:15:15):

100 kg/feddan (240 kg / ha), of the balance compound fertilizer was splitted in two equal doses after one and two month from transplanting.

5- Ammonium sulphate (21% N and 24%S):

100 kg/feddan (240 kg / ha), of the ammonium sulphate splited in two equal doses one and two from transplanting.

3.1.4. Cultural practices:

The soil was ploughed, leveled and then divided to 60 cm ridges running North South, 3 m long. Gross plot size was 10.8 m^2 (4.5 m × 2.4m) with three ridges in each plot, while the net plot size planted was (5.4 m^2).

Onion seedlings were transplanted on 18 – 21 January, 2016 and 20 – 23 January 2017. Seedlings were transplanted in 3 rows on each ridge, with in – row spacing of 7.5 cm, the experiment was replanted 10-12 day after transplanting. The experiment was irrigated (18 and 17 times, respectively) during the seasons at 7 - 10 days intervals. Weeds were cultivated manually twice and three times during the two seasons.

The organic fertilizer (Elshmokh) was added as one dose before transplanting and then irrigated , while the mineral fertilizers (urea, NPK and ammonium sulphate) were applied as two equal doses one and two months after transplanting .

Pest and diseases control was done as recommended when required.

The crop was harvested after the maturity symptoms (50-70 % neck fall) were observed.

3.1.5. Data collected:

3.1.5.1. Plant vegetative growth parameters (Plant characters):

Five plants were selected randomly from each plot 90 days from transplanting to estimate the following parameters:-

3.1.5.1.1. Plant height (cm):

The plant height of the five plants was measured from the ground level to the tip of the neck in centimeter (cm) using standard ruler and the average height was calculated.

3.1.5.1.2. Number of leaves:

The number of leaves of the same plants was determined by counting the green and dry leaves and the average of leaf number calculated.

3.1.5.1.3. Leaf length (cm):

Leaf length was measured for the three longest leaves of the same plants from each plant, it was from the neck of the bulb to the tip of the leaves in centimeter (cm) using standard ruler and the average of leaf length calculated.

3.1.5.2. Bulb yield and yield components:

At harvest the bulbs were cured on mesh sacks for 10-15 days to cure, then the necks were cut and the following data was recorded:-

3.1.5.2.1 .Average bulb weight (g):

Five bulbs were selected randomly from sound (single bulbs and true to cultivars) weight per bulb was calculated.

3.1.5.2.2. Total bulbs yield (t/ha):

The total yield /plot were recorded from 1.8 m^2 and the yield /ha were calculated as follows:

$$\mathbf{Yield\ (t/ha)} = \frac{\mathbf{plot\ yield(kg)}}{\mathbf{plot\ area}} \times \frac{\mathbf{10000}}{\mathbf{1000}}$$

3.1.5.2.3. Marketable bulbs yield (t/ha):

The total yield of sound (single) bulbs/plot was recorded and the yield/ha calculated as for total yield.

$$\mathbf{Marketable\ Yield\ (t/ha)} = \frac{\mathbf{marketable\ plot\ yield\,(kg)}}{\mathbf{plot\ area}} \times \frac{\mathbf{10000}}{\mathbf{1000}}$$

3.1.5.2.4. Percentage of double bulbs:

The double bulbs/plot was weighed in kg and their percentage from the yield/plot was calculated.

3.1.5.2.5. Percentage of bolted bulbs:

The weight of bolted bulbs/plot was recorded in kg and their percentage weight was calculated as for the double bulbs.

3.1.5.3. Onion bulb quality:

Sample of five bulbs was randomly taken from each plot to determine the bulb quality.

3.1.5.3.1. Bulb diameter (cm):

Five sound bulbs were randomly selected from each experimental unit to measure the bulb diameter using the vernier and the average diameter was calculated.

3.1.5.3.2. Bulb length (cm):

The bulb length of the same bulbs was recorded and the average bulb length was calculated.

3.1.5.3.3. Neck diameter (cm):

The neck diameter of the same bulbs was measured using verneir and the average bulb neck diameter (cm) was calculated.

3.1.5.3.4. Number of rings / bulb:

The number of rings of the same bulbs was counted and the average ring number was recorded.

3.1.5.3.5. Total soluble solids (TSS):

The TSS of the same bulbs was recorded using a digital refractometer and the average bulb TSS was recorded.

3.1.5.3.6. Bulb dry matter content (DM %):

The fresh weight of five randomly selected bulbs was recorded in Kg. They were oven dried at 80°C for 48 hours to stable weight which is then recorded and the content of bulb dry mater was calculated using the following equation:

$$\text{Percentage of dry matter} = \frac{\text{Bulbs dry weight}}{\text{Bulbs fresh weight}} \times 100$$

3.1.6. Experimental design and Statistical analysis:

The treatments were arranged in split–plot design of three replications, where the fertilizers were randomized in the main plots and onion cultivars in the sub–plots. The data were analyzed using GenStat (Computer Program) Version4 and the means were separated using Duncan Multiple Range Test (DMRT) at P≤0.05 (Gomez and Gomez, 1984).

CHAPTER FOUR

Results

4. 1. Growth parameters:

4.1.1. Plant height (cm):

The data presented in Table1-1, clearly indicated that plant height was not significantly affected by the different fertilizers type in both seasons (2015/16 and 2016/17), while the significant variation among onion cultivars after three months from transplanting was observed. The cultivars Kamleen and Baftaim (S) recorded the tallest plants (9.53 and 9.42 cm, respectively) whereas; cultivar Texas Early Yellow Grano (6.41 cm) showed the shortest plants in the first season. The cultivar Baftaim (S) gave the tallest plants (11.17 cm), while the cultivars Saggai Improved, Texas Early Grano and Abu-Freiwa (9.29, 9.13 and 8.70 cm, respectively) gave shorter plants in the second season. Interactions among fertilizers and cultivars were not significant.

Combined analysis for the two seasons reflected significant differences among onion cultivars. Baftaim (S) and Kamleen attained the highest plants (10.30 cm and 9.83 cm, respectively), whereas the cultivar Texas Early Yellow Grano gave the shortest plants (7.77 cm) but no significant effects for fertilizers and cultivars interactions (Table 1-2).

4.1.2. Number of leaves/plant:

There were significant effects of the fertilizers on the number of leaves per plant in the first season; urea recorded the highest number of leaves (10.23 leaves/plant). The control and organic fertilizer did not differ significantly from urea, while the NPK

Table (1-1): Effects of fertilizers, onion cultivars and their interactions on plant height (cm) after three months from transplanting:

Fertilizers	Plant height (cm)											
	Season 2015/16						Season 2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	8.41 a	7.49 a	8.86 a	9.40 a	6.10 a	8.05 a	12.07 a	9.37 a	8.33 a	9.40 a	9.85 a	9.80 a
Urea (46%N)	9.70 a	8.20 a	9.30 a	10.00 a	6.89 a	8.82 a	11.17 a	8.80 a	9.10 a	10.67 a	8.77 a	9.70 a
Organic (Elshmokh)	9.63 a	8.17 a	8.10 a	8.19 a	6.47 a	8.11 a	10.57 a	9.50 a	8.77 a	10.53 a	8.90 a	9.65 a
NPK (15:15:15)	10.19 a	8.84 a	8.67 a	10.20 a	6.23 a	8.82 a	10.93 a	9.33 a	9.03 a	9.97 a	9.27 a	9.71 a
Ammonium sulphate (21%N&24%S)	9.19 a	8.33 a	8.33 a	9.83 a	6.37 a	8.41 a	11.10 a	9.43 a	8.26 a	10.10 a	8.87 a	9.55 a
Mean	9.42 a	8.21 b	8.65 b	9.53 a	6.41 c		11.17 a	9.29 c	8.70 c	10.13 b	9.13 c	
Fertilizers LSD	0.926						1.274					
Cultivars LSD	0.653						0.831					
Fertilizers * Cultivars LSD	1.534						2.000					
C.V.%	10.5						11.6					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (1-2): Effects of fertilizers and onion cultivars on plant height (cm) after three months from transplanting:

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	8.05 a	9.80 a	8.93 a
Urea (46%N)	8.82 a	9.70 a	9.26 a
Organic (Elshmokh)	8.11 a	9.65 a	8.88 a
NPK (15:15:15)	8.82 a	9.71 a	9.27 a
Ammonium sulphate (21%N&24%S)	8.41 a	9.55 a	8.98 a
Fertilizers LSD	0.816	0.816	0.577
Cultivars			
Baftaim (S)	9.42 bc	11.17 a	10.30 a
Saggai lmproved	8.21 d	9.29 bc	8.75 b
Abu-Freaiwa	8.65 cd	8.70 cd	8.68 b
Kamleen	9.53 bc	10.13 b	9.83 a
Texas Early Yellow Grano	6.41 e	9.13 c	7.77 c
Cultivars LSD	0.816	0.816	0.577
C.V.%	12.4		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (2-1): Effects of fertilizers, onion cultivars and their interactions on the number of leaves / plant after three months from transplanting:

Fertilizers	Number of Leaves / plant											
	Season 2015/16						Season 2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	10.27 a	9.80 a	9.33 a	10.80 a	8.53 a	9.75 abc	13.40 a	12.73 a	12.53 a	13.33 a	11.90 a	12.78 a
Urea (46%N)	11.00 a	10.13 a	10.87 a	10.80 a	8.33 a	10.23 a	12.27 a	11.73 a	11.20 a	12.47 a	12.07 a	11.95 a
Organic (Elshmokh)	10.20 a	9.67 a	10.67 a	9.53 a	9.13 a	9.84 ab	12.47 a	12.47 a	11.13 a	11.27 a	12.47 a	11.96 a
NPK (15:15:15)	9.40 a	9.43 a	10.00 a	9.87 a	7.73 a	9.29 c	12.6a a	11.40 a	10.93 a	11.20 a	12.93 a	11.83 a
Ammonium sulphate (21%N&24%S)	9.13 a	9.40 a	9.93 a	10.33 a	8.40 a	9.44 bc	13.07	12.27 a	10.57 a	12.93 a	12.20 a	12.21 a
Mean	10.00 ab	9.69 b	10.16 ab	10.27 a	8.43 c		12.77	12.12 a	11.27 b	12.24 a	12.31 a	
Fertilizers LSD	0.518						1.091					
Cultivars LSD	0.460						0.739					
Fertilizers * Cultivars LSD	1.022						1.757					
C.V.%	6.4						8.2					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (2-2): Effects of fertilizers and onion cultivars on the number of leaves per plant after three months from transplanting:

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	9.75 cd	12.78 a	11.26 a
Urea (46%N)	10.23 c	11.95 b	11.09 a
Organic (Elshmokh)	9.84 cd	11.96 b	10.90 ab
NPK (15:15:15)	9.29 d	11.83 b	10.56 b
Ammonium sulphate (21%N&24%S)	9.44 d	12.21 ab	10.82 ab
Fertilizers LSD	0.657	0.657	0.465
Cultivars			
Baftaim (S)	10.00 c	12.77 a	11.39 a
Saggai lmproved	9.69 c	12.12 a	10.90 ab
Abu-Freaiwa	10.16 c	11.27 b	10.72 bc
Kamleen	10.27 c	12.24 a	11.25 a
Texas Early Yellow Grano	8.43 d	12.13 a	10.37 c
Cultivars LSD	0.657	0.657	0.465
C.V.%	8.3		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

fertilizer gave the lowest number of leaves (9.29 leaves/plant), in the second season no significant differences were recorded among fertilizers (Table 2-1).

Onion cultivars in the first season differed significantly, cultivars Kamleen and Abu-Freaiwa and Baftaim (S) gave the highest number of leaves (10.27, 10.16 and 10.00 leaves/plant respectively), Texas Early Yellow Grano gave the lowest number of leaves per plant (8.43), whereas no significant differences were noticed among cultivars except the cultivar Abu-Freaiwa gave the lowest number of leaves (11.27) in the second season as shown in (Table 2-1), the interactions among fertilizers and cultivars were not significant.

Generally, in the combined analysis (Table 2-2), control and urea fertilizer gave, the highest number of leaves 11.26 and 11.09 leaves/plant, respectively, NPK gave the lowest number of leaves per plant (10.56). Significant differences were observed among onion cultivars. Baftaim (S) and Kamleen attained 11.39 and 11.25 leaves per plant, while the cultivar Texas Early Yellow Grano gave the lowest number of leaves (10.37). There were no significant effect from the interactions among fertilizers and cultivars.

4.1.3. Leaf length (cm):

The leaf length varied significantly among onion cultivars as shown in table (3-1). Cultivars Baftaim (S), Kamleen and Saggai Improved gave the longest leaves length (57.24, 56.59 and 53.15 cm, respectively), while cultivar Texas Early Yellow Grano gave the shortest leaf length (47.02 cm) in season 2015/16, but in season 2016/17 cultivar Abu-Freiwa varied significantly from other cultivars, it gave the shortest leaf length (48.21cm).

Table (3-1): Effects of fertilizers, onion cultivars and their interactions on the leaf length (cm) after three months from transplanting:

Fertilizers	Leaf Length (cm)											
	Season 2015/16						Season 2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	55.83 a	47.50 a	52.61 a	54.89 a	45.89 a	51.34 a	56.47 a	55.33 a	51.00 a	52.00 a	54.47 a	53.85 a
Urea (46%N)	59.33 a	52.49 a	52.54 a	53.79 a	49.83 a	53.60 a	57.87 a	51.80 a	46.40 a	55.57 a	50.93 a	52.51 a
Organic (Elshmokh)	56.36 a	49.57 a	46.87 a	62.52 a	44.33 a	51.93 a	49.20 a	52.97 a	47.70 a	50.63 a	49.87 a	50.07 a
NPK (15:15:15)	58.51 a	52.68 a	54.27 a	54.82 a	46.53 a	53.36 a	54.90 a	51.83 a	49.53 a	55.13 a	55.23 a	53.33 a
Ammonium sulphate (21%N&24%S)	56.16 a	63.53 a	52.86 a	56.94 a	48.50 a	55.60 a	56.80 a	51.57 a	46.43 a	50.13 a	53.87 a	51.76 a
Mean	57.24 a	53.15 ab	51.83 b	56.59 ab	47.02 c		55.05 a	52.70 a	48.21 b	52.69 a	52.87 a	
Fertilizers LSD	6.192						5.022					
Cultivars LSD	4.636						3.052					
Fertilizers * Cultivars LSD	10.704						7.530					
C.V.%	11.8						7.9					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (3-2): Effects of fertilizers and onion cultivars on the leaf length (cm) after three months from transplanting:

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	51.34 a	53.85a	52.60 a
Urea (46%N)	53.60 a	52.51a	53.05 a
Organic (Elshmokh)	51.93 a	50.07 a	51.00 a
NPK (15:15:15)	53.36 a	53.33 a	53.34 a
Ammonium sulphate (21%N&24%S)	55.60 a	51.76 a	53.68 a
Fertilizers LSD	4.504	4.504	3.185
Cultivars			
Baftaim (S)	57.24 a	55.05 ab	56.14 a
Saggai lmproved	53.15 ab	52.70 abc	52.93 ab
Abu-Freaiwa	51.83 bc	48.21 cd	50.02 b
Kamleen	56.59 ab	52.69 abc	54.64 a
Texas Early yellow Grano	47.02 d	52.87 abc	49.95 b
Cultivars LSD	4.504	4.504	3.185
C.V.%	11.8		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

No significant effects (Table 3-1) on leaf length were noticed among fertilizers or interactions of fertilizers and cultivars.

Combined analysis (Table 3-2) showed that onion cultivars significantly differed in leaf length, Baftaim (S) attained the longest leaf length (56.14cm) and cultivar Texas Early Yellow Grano gave the shorter leaf length (49.95cm). Leaf length was not affected by fertilizers or interactions of fertilizers and cultivars.

4.2. Yield and yield components:

4.2.1. Single bulb fresh weight (g):

Single bulb fresh weight as in table (4-1), indicated marked differences among onion cultivars, Texas Early Yellow Grano and Baftaim (S) gave the highest bulb fresh weight (64.1 and 55.9 g, respectively), but cultivar Baftaim (S) did not differ significantly from cultivars Kamleen and Saggai Improved (47.8 and 45.9 g, respectively) in the first season. Texas Early Yellow Grano recorded the highest bulb fresh weight (83.1 g) in the second season. The lowest bulb fresh weights were obtained by cultivar Saggai Improved and Abu-Freaiwa (41.4 and 36.2 g, respectively) but not significantly different from Kamleen in both seasons.

No significant variations in single fresh weight among fertilizers or their interaction with cultivars (Table 8-1) were observed in both seasons.

Combined analysis of the two seasons, reflected marked differences among onion cultivars due to seasons. Texas Early Grano gave the heaviest bulbs (73.6 g), and cultivar Abu-Freaiwa gave 40.1g, not significantly different from Saggai Improved and Kamleen (43.7 and 46.1g, respectively). No significant effects on the bulb fresh weight were noticed due to fertilizers or their interaction with cultivars (Table 4-2).

Table (4-1): Effects of fertilizers, onion cultivars and their interactions on single bulb fresh weight (g):

Fertilizers	Single Bulb Fresh Weight (g)											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	53.8 a	41.2 a	44.1 a	52.8 a	49.6 a	48.3 a	76.9 a	42.5 a	42.9 a	46.2 a	70.3 a	55.8 a
Urea (46%N)	53.5 a	56.6 a	44.1 a	49.4 a	64.7 a	53.7 a	93.1 a	42.3 a	46.2 a	37.7 a	83.6 a	60.6 a
Organic (Elshmokh)	66.8 a	40.7 a	36.7 a	39.5 a	62.0 a	49.1 a	65.5 a	45.2 a	35.7 a	55.0 a	88.3 a	57.9 a
NPK (15:15:15)	51.0 a	49.7 a	48.9 a	43.8 a	57.3 a	50.1 a	67.7 a	44.8 a	26.2 a	42.2 a	85.5 a	53.3 a
Ammonium sulphate (21%N&24%S)	54.5 a	41.4 a	46.2 a	53.8 a	86.7 a	56.5 a	49.7 a	32.3 a	30.0 a	41.1 a	87.9 a	48.2 a
Mean	55.9 ab	45.9 bc	44.0 c	47.8 bc	64.1 a		70.6 b	41.4 c	36.2 c	44.4 c	83.1 a	
Fertilizers LSD	11.72						15.88					
Cultivars LSD	10.16						11.72					
Fertilizers * Cultivars LSD	22.66						27.16					
C.V.%	26.7						28.8					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (4-2): Effects of fertilizers and onion cultivars on single bulb fresh weight (g):

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	48.3 a	55.8 a	52.0 a
Urea (46%N)	53.7 a	60.6 a	57.1 a
Organic (Elshmokh)	49.1 a	57.9 a	53.5 a
NPK (15:15:15)	50.1 a	53.3 a	51.7 a
Ammonium sulphate (21%N&24%S)	56.5 a	48.2 a	52.4 a
Fertilizers LSD	12.30	12.30	8.70
Cultivars			
Baftaim (S)	55.9 cd	70.6 b	63.3 b
Saggai lmproved	45.9 de	41.4 e	43.7 c
Abu-Freaiwa	44.0 de	36.2 e	40.1 c
Kamleen	47.8 de	44.4 de	46.1 c
Texas Early Yellow Grano	64.1 bc	83.1 a	73.6 a
Cultivars LSD	12.30	12.30	8.70
C.V.%	31.8		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

4.2.2. Total yield (t/ha):

The total yield t/ha was significantly different among cultivars (Table 5-1), the highest bulb yield per hectare (31.12 t/ha) was recorded by the cultivar Baftaim (S), and the lowest yield (21.28 t/ha) was recorded by Saggai Improved in first season. However, in the second season the highest total yield was recorded by Baftaim (S) and Texas Early Yellow Grano (34.23 and 33.95 t/ha respectively), while the cultivar Abu-Freaiwa reported the lowest total yield (19.51 t/ha).

Moreover, there were no significant effects due to fertilizers in both seasons; however, the interactions among fertilizers and cultivars were significant in the first season. The highest total yield was recorded by Baftaim (S) with urea 36.06, organic 34.17 and NPK 33.48 t/ha, while Texas Early Yellow Grano recorded the highest yield with urea and ammonium sulphate (34.15 and 33.56 t/ha, respectively). The lowest total yield was obtained by the cultivar Saggai Improved with urea (16.89 t/ha).

Generally, combined analysis, reflected that there were no significant differences among fertilizers, while significant variation were observed among cultivars. Baftaim (S) and Texas Early Yellow Grano attained the highest total yields (32.67 and 30.69 t/ha, respectively), whereas, Saggai Improved and Abu-Freaiwa attained the lowest yields (22.79 and 22.21t/ha, respectively). Moreover, the interactions among fertilizers and cultivars reflected significant differences. The highest total yield was obtained yield by Baftaim (S) with all fertilizers (urea, NPK, ammonium sulphate and organic 35.67, 33.69, 32.98 and 32.58 t/ha, respectively) whereas the highest of Texas Early Yellow Grano was obtained with ammonium sulphate, organic and urea (35.19, 32.38 and31.59 t/ha, respectively. The lowest yields were attained by Saggai Improved with ammonium sulphate (19.88 t/ha) and Abu-Freaiwa with urea (19.88 t/ha) (Table 5-2).

Table (5-1): Effects of fertilizers, onion cultivars and their interactions on total yield (t/ha):

Fertilizers	Total Yield (t/ha)											
	Season 2015/16						Season 2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	25.78 bc	24.72 bc	26.89 bc	27.50 b	24.11 bc	٢٥,٨٠ a	31.11 a	24.68 a	21.26 a	25.43 a	32.31 a	26.96 a
Urea (46%N)	36.06 a	16.89 e	22.04 cd	27.57 b	34.15 a	٢٧,٣٤ a	35.28 a	24.87 a	17.04 a	31.81 a	29.04 a	27.61 a
Organic (Elshmokh)	34.17 a	21.63 cde	23.32 bcd	24.76 bc	26.58 bc	٢٦,٠٩ a	31.00 a	23.38 a	22.02 a	24.78 a	38.19 a	27.87 a
NPK (15:15:15)	33.48 a	24.44 bc	26.17 bc	22.44 bcd	18.78 de	٢٥,٠٦ a	33.89 a	27.50 a	19.83 a	30.13 a	33.39 a	28.95 a
Ammonium sulphate (21%N&24%S)	26.09 bc	18.72 de	26.18 bc	25.17 bc	33.56 a	٢٥,٩٤ a	39.87 a	21.03 a	17.41 a	22.87 a	36.82 a	27.60 a
Mean	31.12 a	21.28 d	24.92 c	25.49 bc	27.43 b		34.23 a	24.29 b	19.51 c	27.00 b	33.95 a	
Fertilizers LSD	3.177						2.296					
Cultivars LSD	2.277						3.314					
Fertilizers * Cultivars LSD	5.321						6.889					
C.V.%	11.8						16.2					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (5-2): Effects of fertilizers, onion cultivars and their interactions on total yield (t/ha):

Fertilizers	Season 2015/16	Season 2016/17	Mean
Control (without fertilizer)	25.80 ab	26.96 ab	26.38 a
Urea (46%N)	27.34 ab	27.61 ab	27.47 a
Organic (Elshmokh)	26.09 ab	27.87 ab	26.98 a
NPK (15:15:15)	25.09 b	28.95 a	27.01 a
Ammonium sulphate (21%N&24%S)	25.94 ab	27.60 ab	26.77 a
Fertilizers LSD	2.854	2.854	2.018
Cultivars			
Baftaim (S)	31.12 b	34.23 a	32.67 a
Saggai lmproved	21.28 d	24.29 c	22.79 c
Abu-Freaiwa	29.92 c	19.51 d	22.21 c
Kamleen	25.49 c	27.00 c	26.25 b
Texas Early yellow Grano	27.42 c	33.95 ab	30.69 a
Cultivars LSD	2.854	2.854	2.018
Fertilizers * Cultivars			
Control* Baftaim (S)	25.78 hijklmno	31.11 bcdefghijk	28.44 cde
Control* Saggai lmproved	24.72 ijklmnopqr	24.68 ijklmnopqr	24.70 defghi
Control* Abu-Freaiwa	26.89 fghijklmn	21.26 mnopqr	24.07 feghi
Control* Kamleen	27.50 fghijklmn	25.43 ijklmno	26.46 defg
Control* Texas Early Yellow Grano	24.11 jklmnopqr	32.31 abcdefghi	28.21 cdef
Urea (46%N) * Baftaim (S)	36.06 abcd	35.28 abcde	35.67 a
Urea (46%N) * Saggai lmproved	16.89 r	24.87 ijklmnoq	20.88 hi
Urea (46%N) * Abu-Freaiwa	22.04 mnopqr	17.04 qr	19.54 i
Urea (46%N) * Kamleen	27.57 efghijklmn	31.81 bcdefghij	29.69 bcd
Urea (46%N) * Texas Early Yellow Grano	34.15 abcdef	29.04 defghijklm	31.59 abc
Organic (Elshmokh) * Baftaim (S)	34.17 abcdef	31.00 bcdefghijk	32.58 abc
Organic (Elshmokh) * Saggai lmproved	21.63 mnopqr	23.38 klmnopqr	22.51 ghi
Organic (Elshmokh) * Abu-Freaiwa	23.32 klmnopqr	22.02 mnopqr	22.67 ghi
Organic (Elshmokh) * Kamleen	24.76 ijklmnopqr	24.78 ijklmnopqr	24.77 defhgi
Organic (Elshmokh) * Texas Early Yellow Grano	26.58 fghijklmno	38.19 ab	32.38 abc
NPK (15:15:15) * Baftaim (S)	33.48 abcdefgh	33.89 abcdefg	33.69 ab
NPK (15:15:15) * Saggai lmproved	24.44 ijklmnopqr	27.50 efghijklmn	25.97 defgh
NPK (15:15:15) * Abu-Freaiwa	26.17 ghijklmno	19.38 nopqr	23.00 fghi
NPK (15:15:15) * Kamleen	22.44 lmnopqr	30.13 cdefghijkl	26.29 defg
NPK (15:15:15) * Texas Early Yellow Grano	18.78 opqr	33.39 abcdefgh	26.08 defgh
Ammonium sulphate (21%N&24%S) * Baftaim (S)	26.09 ghijklmno	39.87 a	32.98 abc
Ammonium sulphate (21%N&24%S) * Saggai lmproved	18.72 opqr	21.03 nopqr	19.88 i
Ammonium sulphate (21%N&24%S) * Abu-Freaiwa	26.18 ghijklmno	17.41 pqr	21.79 ghi
Ammonium sulphate (21%N&24%S) * Kamleen	25.17 ijklmnop	22.87 lmnopqr	24.02 efghi
Ammonium sulphate (21%N&24%S) * Texas Early Yellow Grano	33.56 abcdefgh	36.82 abc	35.19 a
Fertilizers* Cultivars LSD	6.382	6.382	4.513
C.V.%	14.6		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

4.2.3. Marketable yield (t/ha):

Data in table (6-1) indicated marked significant differences among onion cultivars. Baftaim (S) and Texas Early Yellow Grano (24.58 and 23.10 t/ha) attained the highest marketable yields in both seasons. In season 2015/16 however, no significant differences between Baftaim (S) (24.58 t/ha) and Texas Early Yellow Grano (23.10 t/ha) were noticed. Moreover, in 2016/17 the cultivar Texas Early Yellow Grano gave the highest marketable yield (28.03 t/ha) compared to other cultivars, whereas the lowest marketable yield in both seasons was reported by Saggai Improved (14.24 and 10.69 t/ha).

As indicated in the same table, in the first season urea (20.73 t/ha), showed the significant highest marketable yield compared to ammonium sulphate (16.83 t/ha), whereas no significant differences marketable yield due to fertilizers were noticed in the second season.

Onion cultivars varied significantly in their response to fertilizers type in both seasons. The highest marketable yields of Texas Early Yellow Grano and Baftaim (S) (30.76 and 30.11 t/ha, respectively) were obtained with urea in the first season, also Kamleen obtained by urea the high marketable yield (19.52 t/ha). Saggai Improved and Abu-Freaiwa, showed no significant response to fertilizers, the highest marketable yields obtained with no fertilizers (18.07 and 18.54 t/ha, respectively) in the first season. In the second season high yield of Texas Early Yellow Grano and Baftaim (S) (34.65 and 30.28 t/ha, respectively) were obtained with organic and ammonium sulphate, respectively but were not significantly different. Kamleen obtained with urea the high marketable yield (16.26 t/ha), while Abu-Freaiwa and Saggai Improved with NPK gave (14.44 and 12.87 t/ha, respectively) (Table 6-1).

Table (6-1): Effects of fertilizers, onion cultivars and their interactions on marketable yield (t/ha):

Fertilizers	Marketable Yield(t/h)											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	22.32 cde	18.07 efgh	18.54 efgh	18.00 efgh	20.39 defg	19.46 ab	23.61 cd	11.39 efg	13.61 Ef	15.98 e	27.78 bc	18.47 a
Urea (46%N)	30.11 ab	10.89 jk	12.39 Ijk	19.52 efgh	30.76 a	20.73 a	23.33 cd	10.56 fg	13.98 Ef	16.26 e	22.78 cd	17.38 a
Organic (Elshmokh)	21.98 cdef	16.24 ghi	17.91 efgh	16.54 ghi	22.28 cde	18.99 ab	22.37 d	10.98 efg	5.00 h	12.22 efg	34.65 a	17.04 a
NPK (15:15:15)	25.44 bcd	15.67 ghij	16.98 fghi	15.68 ghij	15.87 ghij	17.93 ab	23.24 cd	12.87 efg	14.44 Ef	16.11 e	29.21 b	19.18 a
Ammonium sulphate (21%N&24%S)	23.04 cde	10.33 k	9.89 k	14.67 hijk	26.20 abc	16.83 b	30.28 ab	7.65 gh	11.06 efg	14.16 ef	25.74 a	17.78 a
Mean	24.58 a	14.24 c	15.14 bc	16.88 b	23.10 a		24.57 b	10.69 d	11.62 d	14.95 c	28.03 a	
Fertilizers LSD	3.347						3.185					
Cultivars LSD	2.149						2.304					
Fertilizers * Cultivars LSD	5.199						5.370					
C.V.%	15.5						17.4					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (6-2): Effects of fertilizers, onion cultivars and their interactions on marketable yield (t/ha):

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	19.46 ab	18.47 ab	18.97 a
Urea (46%N)	20.73 a	17.38 b	19.06 a
Organic (Elshmokh)	18.99 ab	17.04 b	18.02 a
NPK (15:15:15)	17.93 b	19.18 ab	18.55 a
Ammonium sulphate (21%N&24%S)	16.83 b	17.78 b	17.30 a
Fertilizers LSD	2.464		1.742
Cultivars			
Baftaim (S)	24.58 b	24.57 b	24.57 a
Saggai lmproved	14.24 c	10.69 d	12.47 c
Abu-Freaiwa	15.14 c	11.62 d	13.38 c
Kamleen	16.88 c	14.95 c	15.91 b
Texas Early Yellow Grano	23.10 b	28.03 a	25.57 a
Cultivars LSD	2.464		1.742
Fertilizers * Cultivars			
Control* Baftaim (S)	22.32 defghij	23.61 cdefg	22.96 bc
Control* Saggai lmproved	18.07 ghijklmn	11.39 nopqr	14.73 defg
Control* Abu-Freaiwa	18.54 ghijklm	13.61 klmnopq	16.08 de
Control* Kamleen	18.00 ghijklmn	15.98 jklmnop	16.99 de
Control* Texas Early Yellow Grano	20.39 efghijk	27.78 bcd	24.08 abc
Urea (46%N) * Baftaim (S)	30.11 ab	23.33 cdefg	26.72 ab
Urea (46%N) * Saggai lmproved	10.89 opqr	10.56 opqr	10.72 gh
Urea (46%N) * Abu-Freaiwa	12.39 mnopq	13.98 klmnopq	13.19 efgh
Urea (46%N) * Kamleen	19.52 fghijkl	16.26 ijklmnop	17.89 d
Urea (46%N) * Texas Early Yellow Grano	30.76 ab	22.78 cdefghi	26.77 ab
Organic (Elshmokh) * Baftaim (S)	21.89 defghij	22.37 defghij	22.18 c
Organic (Elshmokh) * Saggai lmproved	16.24 ijklmnop	10.98 opqr	13.61 defg
Organic (Elshmokh) * Abu-Freaiwa	17.91 ghijklmn	5.00 r	11.45 fgh
Organic (Elshmokh) * Kamleen	16.54 hijklmnop	12.22 mnopq	14.38 defg
Organic (Elshmokh) * Texas Early Yellow Grano	22.28 defghij	34.65 a	28.47 a
NPK (15:15:15) * Baftaim (S)	25.44 bcdef	23.24 cdefg	24.34 abc
NPK (15:15:15) * Saggai lmproved	15.67 jklmnop	12.87 lmnopq	14.27 defg
NPK (15:15:15) * Abu-Freaiwa	16.98 ghijklmno	14.44 klmnop	15.71 def
NPK (15:15:15) * Kamleen	15.68 jklmnop	16.11 ijklmnop	15.90 def
NPK (15:15:15) * Texas Early Yellow Grano	15.87 jklmnop	29.21 abc	22.54 bc
Ammonium sulphate (21%N&24%S) * Baftaim (S)	23.04 cdefgh	30.28 ab	26.66 ab
Ammonium sulphate (21%N&24%S) * Saggai lmproved	10.33 opqr	7.65 opqr	8.99 h
Ammonium sulphate (21%N&24%S) * Abu-Freaiwa	9.89 qr	11.06 opqr	10.47 gh
Ammonium sulphate (21%N&24%S) * Kamleen	14.67 klmnop	14.16 klmnopq	14.42 defg
Ammonium sulphate (21%N&24%S) * Texas Early Yellow Grano	26.20 bcde	25.74 bcdef	25.97 abc
Fertilizers* Cultivars LSD	5.509	5.509	3.896
C.V.%	18.5		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

As shown by combined analysis (Table 6-2), there were no significant differences among fertilizers due to seasons. Cultivars Texas Early Yellow Grano, Saggai Improved and Abu-Freaiwa showed significant differences in marketable yield in response to seasons, whereas Baftaim (S) and Kamleen showed no significant response to seasons. However, there were no significant differences among cultivars and fertilizers interaction due to season.

4.2.4. Unmarketable yield:

4.2.4.1. Double bulbs percentage:

Doubling of bulbs was significantly influenced by the onion cultivars in the two seasons (Table 7-1). The lowest percentage of the double bulbs was found in the cultivar Texas Early Yellow Grano (8.0%), while the highest percentage was attained by the cultivar Kamleen (26.5%) in the first season, in the second season the cultivar Texas Early Yellow Grano gave the lowest percentage of double bulbs (17.5%) and the cultivars Saggai Improved and Kamleen obtained the highest percentages of double bulbs (38.6 and 33.0 %). Different types of fertilizers were not found significantly different in the percentages of doubled bulbs in the two seasons.

As in the same table the effect of interactions among fertilizers and cultivars were significant in percentages of double bulbs in the first season. Texas Early Yellow Grano with NPK with the lowest double bulbs percentage (5.74%), on the other hand cultivar Kamleen with ammonium sulphate reported the highest percentage of double bulbs (33.59%), but in the second season there were no significant effects

Table (7-1): Effects of fertilizers, onion cultivars and their interactions on percentage by weight of double bulbs:

Fertilizers	Percentage by weight of double bulbs											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	10.96 abcde	19.88 fg	15.44 abcdef	31.09 hi	7.61 abcd	17.00 a	23.80 a	38.36 a	28.80 a	29.73 a	10.11 a	26.16 a
Urea (46%N)	17.51 def	27.50 ghi	15.57 abcdef	23.11 fgh	6.81 abc	18.10 a	30.33 a	33.76 a	25.20 a	36.32 a	20.42 a	29.21 a
Organic (Elshmokh)	19.88 efg	15.02 abcdef	21.68 fgh	22.57 fgh	6.51 ab	17.13 a	17.46 a	44.05 a	28.63 a	36.41 a	16.75 a	28.66 a
NPK (15:15:15)	20.69 efg	17.81 defg	23.41 fghi	22.10 fgh	5.74 a	17.95 a	25.43 a	36.10 a	27.66 a	32.88 a	20.05 a	28.42 a
Ammonium sulphate (21%N&24%S)	13.47 abcdef	18.86 efg	20.83 efgh	33.59 i	13.40 abcdef	20.03 a	22.35 a	40.85 a	18.41 a	29.75 a	20.02 a	26.27 a
Mean	16.50 b	19.81 b	19.39 b	26.49 c	8.01 a		23.87 ab	38.62 c	25.74 b	33.02 c	17.47 a	
Fertilizers LSD	8.140						9.22					
Cultivars LSD	3.674						7.04					
Fertilizers * Cultivars LSD	10.385						16.16					
C.V.%	27.6						34.4					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (7-2): Effects of fertilizers and onion cultivars on percentage by weight of double bulbs:

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	17.00 a	26.16 a	21.58 a
Urea (46%N)	18.10 a	29.21 a	23.65 a
Organic (Elshmokh)	17.13 a	28.66 a	22.90 a
NPK (15:15:15)	17.95 a	28.42 a	23.19 a
Ammonium sulphate (21%N&24%S)	20.03 a	26.27 a	23.15 a
Fertilizers LSD	6.184	6.184	4.372
Cultivars			
Baftaim (S)	16.50 b	23.87 cde	20.19 b
Saggai lmproved	19.81 bcde	38.62 f	29.22 c
Abu-Freaiwa	19.39 bcd	25.74 de	22.56 b
Kamleen	26.49 e	33.02 f	29.75 c
Texas Early yellow Grano	8.10 a	17.47 bc	12.74 a
Cultivars LSD	6.184	6.184	4.372
C.V.%	37.3		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

on the percentage of double bulbs from all interactions among fertilizers and onion cultivars.

The main results of the two seasons (Table 7-2) for double bulbs percentages reflected significant variations among onion cultivars, cultivar Texas Early Yellow Grano with the lowest percentage of double bulbs (12.74%), whereas the cultivars Saggai Improved and Kamleen with highest percentages (29.22 and 29.75%, respectively). Fertilizers and their interactions with onion cultivars were not significantly different in doubling percentage.

4.2.4.2. Bolted bulbs percentage:

Percentages of bolted bulbs differed significantly among onion cultivars (Table 8-1), In the first season it was observed that the lowest percentages of bolted bulbs (1.00 and 1.11 %) were obtained by the cultivars Texas Early Yellow Grano and Baftaim (S), whereas the highest percentage (1.84 %) was produced by Abu-Freiwa in the first season. Texas Early Yellow Grano gave the lowest percentage (1.41%), while the cultivar Saggai Improved recorded (2.63%) the highest percentage of bolted bulbs in the second season.

The different among fertilizers types and their interactions with onion cultivars were not significantly different in the percentages of bolted bulbs, in the both season.

Combined analysis indicated significant differences among onion cultivars (Table 8-2). Cultivar Texas Early Yellow Grano with the lowest percentage bolted bulbs (1.41%) while the highest percentage was obtained by the cultivar Saggai Improved (2.18%). The effects of fertilizers and their combinations with onion cultivars were not significant.

Table (8-1): Effects of fertilizers, onion cultivars and their interactions on percentage of bolted bulbs:

Fertilizers	Percentage of bolting											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	1.00 a	1.60 a	2.20 a	1.77 a	1.00 a	1.51 b	2.46 a	2.28 a	1.79 a	1.83 a	1.41 a	1.95 a
Urea (46%N)	1.00 a	1.32 a	1.31 a	1.26 a	1.00 a	1.18 a	1.80 a	2.27 a	2.17 a	1.86 a	1.41 a	1.90 a
Organic (Elshmokh)	1.29 a	1.36 a	1.90 a	1.46 a	1.00 a	1.40 ab	1.76 a	3.00 a	1.41 a	3.26 a	1.41 a	2.17 a
NPK (15:15:15)	1.00 a	1.53 a	2.53 a	1.19 a	1.00 a	1.45 a	2.09 a	2.99 a	1.91 a	2.24 a	1.41 a	2.13 a
Ammonium sulphate (21%N&24%S)	1.25 a	1.16 a	1.22 a	1.21 a	1.00 a	1.17 a	1.63 a	2.61 a	1.41 a	1.70 a	1.41 a	1.75 a
Mean	1.11 a	1.39 b	1.84 c	1.38 b	1.00 a		1.95 ab	2.63 c	1.74 ab	2.18 bc	1.41 a	
Fertilizers LSD	0.237						0.573					
Cultivars LSD	0.258						0.573					
Fertilizers * Cultivars LSD	0.554						1.245					
C.V.%	26.1						39.2					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (8-2): Effects of fertilizers and onion cultivars on percentage of bolted bulbs:

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	1.77 a	1.95 a	1.86 a
Urea (46%N)	1.56 a	1.90 a	1.73 a
Organic (Elshmokh)	1.74 a	2.17 a	1.95 a
NPK (15:15:15)	1.79 a	2.13 a	1.96 a
Ammonium sulphate (21%N&24%S)	1.55 a	1.75 a	1.65 a
Fertilizers LSD	0.412	0.412	0.292
Cultivars			
Baftaim (S)	1.50 ab	1.95 bc	1.73 b
Saggai lmproved	1.73 abc	2.63 d	2.18 c
Abu-Freaiwa	2.04 c	1.74 abc	1.89 bc
Kamleen	1.72 abc	2.18 c	1.95 bc
Texas Early Yellow Grano	1.41 a	1.41 a	1.41 a
Cultivars LSD	0.412	0.412	0.292
C.V.%	31.1		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

4.3. Onion bulb quality:

4.3.1. Bulb diameter (cm):

Onion cultivars varied significantly in bulb diameter (Table 9-1) cultivar Texas Early yellow Grano gave the largest bulb diameter (5.56 cm) whereas the smallest diameter recorded by cultivar Abu-Freaiwa (4.29 cm). However, it was not significantly different from that of cultivar Saggai Improved (4.60 cm) in the second season. There were no significant differences among fertilizers or their interaction with cultivars in both seasons.

The results of combined analysis, (Table 9-2) indicated that the onion cultivars varied significantly in bulb diameter. Texas Early Yellow Grano had the highest bulb diameter (5.20 cm) but not significantly different from Baftaim (S) (4.95cm). Abu-Freaiwa gave the lowest bulb diameter (4.43cm) but it was not significantly different from that of both Saggai Improved and Kamleen (4.61 and 4.69 cm, respectively).

4.3.2. Bulb length (cm):

Bulb length (Table 10-1) was significantly influenced by cultivars. Texas Early Yellow Grano gave the longest bulbs (5.24 and 5.19 cm, respectively) in both seasons. Whereas the shortest bulbs obtained by Saggai Improved (3.81cm) and cultivar Abu-Freaiwa (3.48 cm) in the first and second season, respectively.

No significant effects on the bulb length due to fertilizers or interactions with cultivars in the first seasons, but differences were reported for fertilizer in the both season.

The combined analysis (Table 10-2), reflected marked variations among cultivars in bulb length due to season. The longest bulb (5.21cm) was attained by Texas Early Yellow Grano whereas; the shortest one was attained by Abu-Freaiwa and

Table (9-1): Effects of fertilizers, onion cultivars and their interactions on bulb diameter (cm):

Fertilizers	Bulb diameter (cm)											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	4.67 a	4.56 a	4.58 a	4.85 a	4.50 a	4.63 a	5.47 a	4.70 a	4.86 a	4.75 a	5.19 a	5.00 a
Urea (46%N)	4.66 a	4.92 a	4.69 a	4.78 a	4.94 a	4.80 a	5.03 a	4.61 a	4.67 a	4.89 a	5.74 a	4.99 a
Organic (Elshmokh)	5.06 a	4.39 a	4.20 a	4.18 a	4.74 a	4.51 a	5.21 a	4.75 a	4.07 a	4.91 a	5.61 a	4.91 a
NPK (15:15:15)	4.60 a	4.82 a	4.69 a	4.65 a	4.73 a	4.70 a	5.12 a	4.67 a	3.76 a	4.49 a	5.77 a	4.76 a
Ammonium sulphate (21%N&24%S)	4.70 a	4.38 a	4.67 a	4.89 a	5.30 a	4.79 a	4.98 a	4.28 a	4.09 a	4.51 a	5.51 a	4.67 a
Mean	4.74 a	4.61 a	4.56 a	4.67 a	4.84 a		5.16 b	4.60 cd	4.29 d	4.71 c	5.56 a	
Fertilizers LSD	0.460						0.595					
Cultivars LSD	0.320						0.323					
Fertilizers * Cultivars LSD	0.755						0.835					
C.V.%	9.1						9.0					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (9-2): Effects of fertilizers and onion cultivars on bulb diameter (cm):

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	4.63 a	5.00 a	4.81 a
Urea (46%N)	4.80 a	4.99 a	4.89 a
Organic (Elshmokh)	4.51 a	4.91 a	4.71 a
NPK (15:15:15)	4.70 a	4.76 a	4.73 a
Ammonium sulphate (21%N&24%S)	4.79 a	4.67 a	4.73 a
Fertilizers LSD	0.382	0.382	0.270
Cultivars			
Baftaim (S)	7.74 c	5.16 b	4.95 ab
Saggai lmproved	4.61 cd	4.60 cd	4.61 c
Abu-Freaiwa	4.56 cd	4.29 d	4.43 c
Kamleen	4.67 cd	4.71 cd	4.69 bc
Texas Early Yellow Grano	4.84 bc	5.56 a	5.20 a
Cultivars LSD	0.382	0.382	0.270
C.V.%	11.0		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (10-1): Effects of fertilizers, onion cultivars and their interactions on bulb length (cm):

Fertilizers	Bulb length (cm)											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	4.64 a	3.32 a	3.85 a	4.01 a	4.88 a	4.14 a	4.89 a	3.87 a	3.85 a	3.61 a	5.17 a	4.28 a
Urea (46%N)	4.67 a	4.61 a	3.98 a	3.99 a	5.24 a	4.50 a	4.74 a	3.37 a	3.68 a	3.89 a	5.17 a	4.17 ab
Organic (Elshmokh)	4.82 a	3.60 a	3.81 a	3.73 a	5.27 a	4.25 a	4.39 a	3.71 a	3.31 a	4.03 a	5.10 a	4.11 ab
NPK (15:15:15)	4.54 a	3.77 a	3.97 a	3.88 a	4.96 a	4.22 a	4.59 a	3.51 a	3.27 a	3.86 a	5.37 a	4.12 ab
Ammonium sulphate (21%N&24%S)	4.71 a	3.74 a	3.91 a	4.05 a	5.83 a	4.45 a	4.45 a	3.41 a	3.28 a	3.15 a	5.13 a	3.88 b
Mean	4.68 b	3.81 c	3.90 c	3.93 c	5.24 a		4.61 b	3.57 c	3.48 c	3.71 c	5.19 a	
Fertilizers LSD	0.414						0.344					
Cultivars LSD	0.370						0.348					
Fertilizers * Cultivars LSD	0.825						0.755					
C.V.%	11.7						11.6					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (10-2): Effects of fertilizers and onion cultivars on bulb length (cm):

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	4.14 a	4.28 a	4.21 a
Urea (46%N)	5.00 a	4.17 a	4.33 a
Organic (Elshmokh)	4.25 a	4.11 a	4.18 a
NPK (15:15:15)	4.22 a	4.12 a	4.17 a
Ammonium sulphate (21%N&24%S)	4.45 a	4.88 a	4.17 a
Fertilizers LSD	0.367	0.367	0.259
Cultivars			
Baftaim (S)	4.68 a	4.61 a	4.45 b
Saggai lmproved	3.81 a	3.57 a	3.69 c
Abu-Freaiwa	3.90 a	3.48 a	3.69 c
Kamleen	3.93 a	3.71 a	3.82 c
Texas Early Yellow Grano	5.24 a	5.19 a	5.21 a
Cultivars LSD	0.367	0.367	0.259
C.V.%	12.0		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Saggai Improved (3.69 cm). The effect of fertilizers and their interactions with cultivars were not significant.

4.3.3. Bulb neck diameter (cm):

The results (table 11-1) showed that there was no significant effect on neck diameter due to fertilizers in the first season. However, a significant effect due to urea was noticed in the second season.

No significant differences on neck diameter were noticed among cultivars in the first season. Whereas, cultivar Texas Early Yellow Grano obtained the thick neck (0.61cm) in the second season.

The interactions of fertilizers with cultivars showed no significant effects on bulb neck diameter were not differed in the both seasons (table 11-1).

Combined analysis (table 11-2) for the both seasons reflected no significant differences on bulb neck diameter among cultivars and their interactions.

4.3.4. Number of storage leaves/bulb:

As in Table 12-1 no significant differences were noticed among fertilizers with respect to the number of storage leaves in the both seasons.

However, the number of storage leaves varied significantly among onion cultivars. Cultivars Baftaim(S) and Kamleen had the highest number of storage leaves (9.53 and 9.33, respectively). Whereas, other cultivars had the lowest storage leaf number in the first season. In the second season cultivar Texas Early Yellow Grano, Kamleen and Baftaim (S) showed the highest number of storage leaves (8.21, 7.92 and 7.85, respectively) whereas Saggai Improved recorded the lowest number of storage leaves (6.69).

Table (11-1): Effects of fertilizers, onion cultivars and their interactions on neck diameter (cm):

Fertilizers	Bulb neck diameter (cm)											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	0.50 a	0.57 a	0.46 a	0.56 a	0.38 a	0.49 a	0.43 a	0.48 a	0.50 a	0.56 a	0.64 a	0.52 ab
Urea (46%N)	0.52 a	0.39 a	0.51 a	0.49 a	0.44 a	0.47 a	0.64 a	0.44 a	0.55 a	0.58 a	0.65 a	0.57 a
Organic (Elshmokh)	0.48 a	0.51 a	0.44 a	0.38 a	0.51 a	0.46 a	0.37 a	0.43 a	0.50 a	0.49 a	0.61 a	0.48 b
NPK (15:15:15)	0.40 a	0.47 a	0.46 a	0.53 a	0.32 a	0.44 a	0.46 a	0.34 a	0.41 a	0.62 a	0.63 a	0.49 b
Ammonium sulphate (21%N&24%S)	0.49 a	0.45 a	0.49 a	0.51 a	0.43 a	0.48 a	0.41 a	0.41 a	0.47 a	0.30 a	0.53 a	0.42 c
Mean	0.48 a	0.48 a	0.47 a	0.49 a	0.42 a		0.46 a	0.42 a	0.48 a	0.51 a	0.61 b	
Fertilizers LSD	0.121						0.048					
Cultivars LSD	0.074						0.091					
Fertilizers * Cultivars LSD	0.182						0.187					
C.V.%	21.5						25.0					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (11-2): Effects of fertilizers and onion cultivars on neck diameter (cm):

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	0.45 a	0.52 a	0.51 a
Urea (46%N)	0.47 a	0.57 a	0.52 a
Organic (Elshmokh)	0.46 a	0.48 a	0.47 a
NPK (15:15:15)	0.44 a	0.49 a	0.46 a
Ammonium sulphate (21%N&24%S)	0.48 a	0.42 a	0.45 a
Fertilizers LSD	0.063	0.063	0.0903
Cultivars			
Baftaim (S)	0.48 a	0.46 a	0.47 a
Saggai lmproved	0.48 a	0.42 a	0.45 a
Abu-Freaiwa	0.47 a	0.48 a	0.48 a
Kamleen	0.49 a	0.51 a	0.50 a
Texas Early Yellow Grano	0.42 a	0.61 b	0.51 a
Cultivars LSD	0.063	0.063	0.090
C.V.%	25.9		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (12-1): Effects of fertilizers, onion cultivars and their interactions on number of storage leaves / bulb:

Fertilizers	Number of storage leaves / Bulb											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Feraiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Feraiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	10.20 a	8.57 a	8.06 a	9.47 a	8.05 a	8.87 a	8.47 a	6.93 a	7.20 a	8.13 a	8.27 a	7.80 a
Urea (46%N)	9.04 a	8.20 a	9.00 a	8.86 a	7.67 a	8.55 a	7.87 a	5.33 a	7.80 a	6.67 a	8.33 a	7.20 a
Organic (Elshmokh)	8.12 a	8.75 a	8.31 a	9.13 a	8.32 a	8.52 a	7.40 a	7.40 a	6.47 a	8.93 a	7.80 a	7.60 a
NPK (15:15:15)	9.56 a	8.52 a	8.79 a	8.63 a	8.11 a	8.72 a	8.20 a	6.60 a	7.00 a	8.73 a	8.40 a	7.79 a
Ammonium sulphate (21%N&24%S)	10.76 a	8.75 a	9.31 a	10.59 a	8.50 a	8.58 a	7.33 a	7.20 a	6.26 a	7.13 a	8.27 a	7.24 a
Mean	9.53 a	8.56 b	8.69 b	9.33 a	8.13 b		7.85 ab	6.69 c	6.95 bc	7.92 ab	8.21 a	
Fertilizers LSD	0.918						0.747					
Cultivars LSD	0.640						0.998					
Fertilizers * Cultivars LSD	1.507						2.091					
C.V.%	9.8						18.0					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (12-2): Effects of fertilizers and onion cultivars on number of storage leaves / bulb:

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	8.87 a	7.80 a	8.33 a
Urea (46%N)	8.55 a	7.20 a	7.88 a
Organic (Elshmokh)	8.52 a	7.60 a	8.06 a
NPK (15:15:15)	8.72 a	7.79 a	8.25 a
Ammonium sulphate (21%N&24%S)	9.58 a	7.24 a	8.41 a
Fertilizers LSD	0.960	0.960	0.679
Cultivars			
Baftaim (S)	9.53 a	7.85 bc	8.69 a
Saggai lmproved	8.56 ab	8.69 d	7.62 b
Abu-Freaiwa	8.69 ab	6.95 cd	7.82 b
Kamleen	9.33 a	7.92 bc	8.63 a
Texas Early Yellow Grano	8.13 b	8.21 b	8.17 ab
Cultivars LSD	0.960	0.960	0.679
C.V.%	16.2		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

All interactions among fertilizers and onion cultivars were not significant (Table 12-1).

Combined analysis (Table12-2) for the number of storage leaves reflected no significant differences among fertilizers and their interactions with cultivars, but onion cultivars varied significantly in number of storage leaves, the high number of storage leaves attained by cultivars Baftaim (S), Kamleen and Texas Early Yellow Grano (8.69, 8.63 and 8.17, respectively), while the low number of storage leaves were obtained for the cultivars Saggai Improved and Abu-Freaiwa (7.82 and 7.62, respectively).

4.3.5. Total soluble solids (TSS):

Onion cultivars showed marked variations (Table 13-1). Cultivar Kamleen gave the highest total soluble solids in the two seasons (15.01and 13.81, respectively) followed by cultivars Abu-Freaiwa and Saggai Improved, while Baftaim (S) ranked the fourth cultivar and the lowest total soluble solids were obtained for the cultivar Texas Early Yellow Grano in the two seasons (7.09 and 6.89, respectively).

Significant differences among fertilizers were observed in the first season. Control and urea gave the highest total soluble solids (12.91 and 12.51, respectively) and the lowest total soluble solids were recorded by organic fertilizer (11.91), but it did not vary significantly from ammonium sulphate and the NPK fertilizer (12.34 and 12.12, respectively), but in the second season the differences among fertilizers were not significant.

The interactions among fertilizers and onion cultivars were significant in the first season, the highest total soluble solids obtained by combination of control with Kamleen (17.26) while the lowest total soluble solids was obtained by the cultivar Texas Early Yellow Grano with all fertilizers.

Table (13-1): Effects of fertilizers, onion cultivars and their interactions on total soluble solid (TSS):

Fertilizers	Total soluble Solid (T.S.S.) of Bulb											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Feraiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Feraiwa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	13.28 cdefg	13.51 cdefg	13.32 cdefg	17.26 a	7.19 h	12.91 a	12.37 a	12.06 a	12.85 a	13.15 a	6.71 a	11.43 a
Urea (46%N)	13.11 defg	13.33 cdefg	13.77 cdef	15.38 b	6.99 h	12.51 ab	11.48 a	12.83 a	12.24 a	14.44 a	7.11 a	11.62 a
Organic (Elshmokh)	13.05 defg	13.06 defg	13.06 defg	13.98 cde	6.42 h	11.91 c	11.43 a	12.51 a	12.97 a	13.62 a	6.83 a	11.47 a
NPK (15:15:15)	12.41 g	12.69 fg	13.57 cdefg	14.51 bc	7.41 h	12.12 bc	11.23 a	12.45 a	13.42 a	14.02 a	6.99 a	11.62 a
Ammonium sulphate (21%N&24%S)	12.72 efg	13.39 cdefg	14.18 bcd	13.95 cdef	7.46 h	12.34 bc	12.08 a	13.22 a	14.33 a	13.82 a	6.82 a	12.05 a
Mean	12.91 c	13.20 bc	13.58 b	15.01 a	7.09 d		11.72 c	12.61 b	13.16 ab	13.81 a	6.89 d	
Fertilizers LSD	0.445						0.755					
Cultivars LSD	0.601						0.728					
Fertilizers * Cultivars LSD	1.269						1.591					
C.V.%	6.6						8.5					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (13-2): Effects of fertilizers and onion cultivars on total soluble solid (TSS):

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	12.91 a	11.43 a	12.17 a
Urea (46%N)	12.51 a	11.62 a	12.07 a
Organic (Elshmokh)	11.91 a	11.47 a	11.69 a
NPK (15:15:15)	12.12 a	11.62 a	11.87 a
Ammonium sulphate (21%N&24%S)	12.34 a	12.05 a	12.20 a
Fertilizers LSD	0.758	0.758	0.536
Cultivars			
Baftaim (S)	12.91 a	11.72 a	12.32 c
Saggai lmproved	13.20 a	12.61 a	12.91 b
Abu-Feraiwa	13.58 a	13.16 a	13.37 b
Kamleen	15.01 a	13.81 a	14.41 a
Texas Early Yellow Grano	7.09 a	6.89 a	6.99 d
Cultivars LSD	0.758	0.758	0.536
C.V.%	8.7		

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Analysis of the two seasons reflected significant variations among cultivars, Kamleen gave the highest total soluble solids (14.41), whereas the lowest was (6.99) attained by Texas Early Yellow Grano. There were no significant differences among fertilizers or their interactions with cultivars (Table 13-2 and Table 13-1).

4.3.6. Dry matter content:

Significant variations in dry matter were found among onion cultivars in the two seasons (Table 14-1), cultivar Kamleen gave the highest dry matter content (17.32 and 16.29, respectively), but was not significantly different from Saggai Improved (15.25) in the second season, whereas, cultivar Texas Early Yellow Grano gave the lowest dry matter content in the two seasons (7.52 and 7.04, respectively).

The different fertilizers had no significant effect on the dry matter content of bulb in the two seasons (Table 14-1).

Dry matter percentage of bulb showed significant variations among the interactions of fertilizers and onion cultivars in the second season (Table 14-2), cultivar Kamleen produced the highest dry matter percentage of bulb (23.34) with Urea, while the lowest (7.12, 6.86 and 6.40) were produced by cultivar Texas Early Yellow Grano with control, urea and ammonium sulphate, respectively. There were no significant differences of the interactions in the first season.

Combined analysis of the two seasons (Table 14-2) revealed significant differences with respect to dry matter content among onion cultivars, all four cultivars Kamleen, , Saggai Improved, Baftaim (S) and Abu-Freaiwa (15.27, 14.82, 14.21 and 13.87, respectively) varied significantly from Texas Early Yellow Grano (11.23).

Table (14-1): Effects of fertilizers, onion cultivars and their interactions on percentage dry matter of bulb:

Fertilizers	Percentage Dry Matter of Bulb											
	2015/16						2016/17					
	Cultivars						Cultivars					
	Baftaim (S)	Saggai lmproved	Abu-Freaiwa	Kamleen	Texas Early Yellow Grano	Mean	Baftaim (S)	Saggai lmproved	Abu-Freiawa	Kamleen	Texas Early Yellow Grano	Mean
Control (without fertilizer)	14.28 a	15.53 a	15.18 a	19.43 a	6.85 a	14.26 a	13.28 bcd	14.27 bcd	15.69 b	12.55 bcd	7.12 ef	12.58 a
Urea (46%N)	14.04 a	14.87 a	15.27 a	17.45 a	7.85 a	13.90 a	10.95 cde	14.57 bcd	14.62 bcd	23.34 a	6.86 ef	14.07 a
Organic (Elshmokh)	14.84 a	15.70 a	15.82 a	16.70 a	7.82 a	14.17 a	13.48 bcd	15.15 bc	13.23 bc	15.37 bc	7.13 ef	12.87 a
NPK (15:15:15)	13.77 a	14.96 a	16.66 a	16.35 a	6.87 a	13.72 a	12.25 bcd	16.86 bc	16.22 b	15.27 bc	7.69 ef	13.66 a
Ammonium sulphate (21%N&24%S)	12.72 a	14.84 a	15.71 a	16.66 a	8.21 a	13.63 a	16.24 b	15.40 bc	10.53 edf	14.92 bcd	6.40 f	12.61 a
Mean	13.93 c	15.18 b	15.66 b	17.32 a	7.52 d		13.24 c	14.06 ab	13.97 bc	16.29 a	7.04 d	
Fertilizers LSD	0.810						1.710					
Cultivars LSD	0.810						1.710					
Fertilizers * Cultivars LSD	1.811						3.823					
C.V.%	7.9						12.7					

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

Table (14-2): Effects of fertilizers, onion cultivars and their interactions on percentage dry matter of bulb:

Fertilizers	Season		Mean
	2015/16	2016/17	
Control (without fertilizer)	14.26 a	12 58 a	13.42 a
Urea (46%N)	13.90 a	14.07 a	13.98 a
Organic (Elshmokh)	14.17 a	12.87 a	13.52 a
NPK (15:15:15)	13.72 a	13.66 a	13.69 a
Ammonium sulphat (21%N&24%S)	13.63 a	12.61 a	13.16 a
SE±	0.285	0.601	0.328
Cultivars			
Baftaim (S)	13.93 c	13.24 c	13.58 c
Saggai lmproved	15.18 b	15.25 ab	15.22 b
Abu-Freaiwa	15.73 b	14.06 bc	14.89 b
Kamleen	17.32 a	16.29 a	16.88 a
Texas Early Yellow Grano	7.52 d	7.04 d	7.28 d
SE±	0.285	0.601	0.328
Fertilizers * Cultivars			
Control* Baftaim (S)	14.28 a	13.28 bcd	13.78 cde
Control* Saggai lmproved	15.53 a	14.27 bcd	14.90 bcde
Control* Abu-Freaiwa	15.18 a	15.69 b	15.43 bcd
Control* Kamleen	19.43 a	12.55 bcd	15.99 bc
Control* Texas Early Yellow Grano	6.85 a	7.12 ef	6.99 f
Urea (46%N) * Baftaim (S)	14.04 a	10.95 cde	12.49 e
Urea (46%N) * Saggai lmproved	14.87 a	14.57 bcd	14.72 bcde
Urea (46%N) * Abu-Freaiwa	15.27 a	14.62 bcd	14.95 bcd
Urea (46%N) * Kamleen	17.45 a	23.34 a	20.40 a
Urea (46%N) * Texas Early Yellow Grano	7.85 a	6.86 ef	7.36 f
Organic (Elshmokh) * Baftaim (S)	14.84 a	13.48 bcd	14.16 bcde
Organic (Elshmokh) * Saggai lmproved	15.70 a	15.15 bc	15.42 bcd
Organic (Elshmokh) * Abu-Freaiwa	15.82 a	13.23 bcd	14.52 bcde
Organic (Elshmokh) * Kamleen	16.70 a	15.37 bc	16.03 bc
Organic (Elshmokh) * Texas Early Yellow Grano	7..82 a	7.13 ef	7.47 f
NPK (15:15:15) * Baftaim (S)	13.77 a	12.25 bcd	13.01 de
NPK (15:15:15) * Saggai lmproved	14.96 a	16.86 b	15.91 bc
NPK (15:15:15) * Abu-Freaiwa	16.66 a	16.22 b	16.44 b
NPK (15:15:15) * Kamleen	16.35 a	15.27 bc	15.81 bc
NPK (15:15:15) * Texas Early Yellow Grano	6.87 a	7.69 ef	7.28 f
Ammonium sulphate (21%N&24%S) * Baftaim (S)	12.72 a	16.24 b	14.48 bcde
Ammonium sulphate (21%N&24%S) * Saggai lmproved	14.84 a	15.40 bc	15.12 bcd
Ammonium sulphate (21%N&24%S) * Abu-Freaiwa	15.71 a	14.06 def	13.12 de
Ammonium sulphate (21%N&24%S) * Kamleen	16.66 a	14.92 bcd	15.79 bc
Ammonium sulphate (21%N&24%S) * Texas Early Yellow Grano	8.21 a	6.40 f	7.30 f
SE±	0.637	1.344	0.735
C.V.%	7.9	17.7	18.5

Means with similar letters were not significantly different at P=0.05 according to Duncan Multiple Range Test (DMRT).

CHAPTER FIVE

Discussion

Vegetative growth (Plant characters):

The results indicated some variations in plant characters (plant height, number of leaves and leaf length) among onion cultivars, Baftaim (S) and Kamleen were with vigor growth; of tall plants, large number of leaves per plant and tall leaf length after 90 days from transplanting followed by the cultivars Saggai Improved and Abu-Freaiwa, however, the cultivar Texas Early Yellow Grano has the shortest plant height, small number of leaves and short leaf length. The variation in plant growth (characters) among cultivars may be related to the genetic make-up. This nresult was confirmed by many researchers. Geries *et al.*, (2012), Mousa (2011) Dawar *et al* (2007) and Ghaffoor *et al.,* (2003), who reported that onion cultivars varied in plant growth characters (plant height, number of leaves and leaf length). Also in Sudan Eltayeb (2006), reported significant variations among local cultivars in plant growth characters. Idriss (2007) also found marked variations among introduced and local cultivars; Baftaim(S) has vigorous growth characters (plant height and leaf length).

Yield and yield components:

The variations in yield and yield components (total, marketable yield, doubling and bolting percentages) varied markedly among the five cultivars in the study.

High total yield per hectare was attained by Baftaim (S) and Texas Early Yellow Grano compared to local cultivars. Kamleen ranked the second and local cultivars Saggai Improved and Abu-Feraiwa were the lowest in total and marketable yield. Texas Early Yellow Grano gave the lowest double and bolted bulbs percentages, whereas the local cultivar Saggai Improved attained the highest percentages. The significant differences among the studied cultivars were perhaps due to genetic variations and degree of purification and selection intensity. It could be also due to significant performance in some other traits such as plant height, number of leaves and other growth characters and environment genotype interaction.

These findings agree with Benti (2017), who observed significant differences with respect to total and marketable yield among onion cultivars and Gautam *et al.*, (2006), who reported that marketable yield was significantly variable among onion cultivars. Also Geries *et al.,* (2012) and Dawar *et al.,* (2007), found that total and marketable yield, and double bulbs weight differed markedly among onion cultivars. Results agree with those of Jillani *et al.*, (2004) and Mousa (2015), who reported significant variations in yield, marketable and unmarketable (double and early bolters) yield among onion cultivars. Similar results were found by Pakyurek *et al.*, (1994), Rumple and Felezynski (1997), Singh and Sachan (1999), Rumple *et al.,* (2000) and Vanparys (1999), who reported that onion cultivars varied significantly in bulb yield and quality. Kimani *et al*., (1993), observed variations in bulb yield among introduced and local cultivars, some of introduced cultivars have a potential and out yielded the local cultivars.

Results reported here indicated that there were variations among the introduced and local cultivars, this finding confirms with Sudanese studies of Mohamedali (2007), Idriss (2007) and Ali *et al.,* (2010) who found that cultivar Baftaim (S) out-yielded other introduced and local cultivars with respect to total and marketable yield. Also the cultivar Baftaim (S) gave the highest marketable yield compared to other cultivars, whereas the local cultivar Abu-Freaiwa had the lowest total and marketable yield and the highest un-marketable yield. Eltayeb (2006), reported marked variations in total, marketable and un-marketable yield among some Sudanese local cultivars.

Onion Bulb quality:

As indicated in the results, significant variations were detected among in physical characters (single bulb fresh weight, bulb diameter, bulb length, bulb neck diameter and number of storage leaves (rings)) of onion bulbs. Texas Early Yellow Grano attained the highest in all physical characters except the number o f storage leaves (rings) whereas Baftaim (S) and Kamleen had the maximum number of storage leaves.

The variations in physical characters among onion cultivars agree with the finding reported by Dawar *et al.,* (2007), Kimani *et al* (1993), Geries *et al.,* (2012), Mousa (2015) and Gautam *et al.,* (2006) they reported significant variations in single bulb weight and bulb dry matter. Also these results agree with some Sudanese studies by Ali *et al.,* (2010) and Idriss (2007), who reported that Baftaim (S) had the heaviest bulbs and maximum bulb diameter, Eltayeb (2006), found that cultivar Kamleen produced heavier bulbs and maximum bulb diameter than other local cultivars.

Total soluble solids were the highest in cultivar Kamleen, while introduced cultivar Texas Early Yellow Grano had the lowest total soluble solids. Results indicated that the highest dry matter content in cultivar Kamleen, cultivars Saggai Improved and Abu-Freaiwa were not varied, but cultivar Texas Early Yellow Grano was the lowest in dry matter content.

Experiment Two

A comparative study on storability of five onions (*Allium cepa* L.) bulbs produced under different fertilizers type.

CHAPTER TWO

Literature Review

2.3. Onion bulbs Storability:

Onion bulbs storage is essential to the onion industry so as, it allows for onions to be available all around the year. Also being a biennial crop, therefore, bulbs for seed production must be stored until the following growing season.
Onion is a seasonal crop, it is grown in the cool dry season and has comparatively low storage ability and bulbs are usually stored until the harvest of next season crop or for longer period due to seasonal glut in the market (Benti, 2017).

The benefit of the storage is to extend the period of availability of crop, maintain optimum bulb quality and minimize losses from physical, physiological, and pathological agents (FAO, 2003).

Storability of onion bulbs poses great problems due to poor pre and post-harvest conditions. Interaction of many factors contributes to quality of bulbs in post-harvest storage and for successful storage; these include cultivars, method of culture, mineral nutrition, harvesting, field curing, handling of bulbs and storage environment. (Biswas *et al*., 2010, Gamiely, *et al*., 1991, Uzo and Currah, 1990, Chung, 1989, Brewester, 2008 and Choudhury, 2006).

Storage is a serious problem in tropical countries, significant losses in quantity and quality of onion occur during storage (Benti, 2017). Due to Lack of the proper stores, onions are stored by farmers with traditional technique in shelters under ambient conditions, (Sohany *et al*., 2016), this traditional storage system results in increased postharvest losses of onion.

Bulb selected for storage, should be firm, with the neck dry and thin. Thick-necked bulbs should be discarded because they are most likely to have high moisture content above the optimum for storage, and therefore would have short storage life, all damaged or diseased bulbs removed, careful harvest and pre-storage treatments with minimal mechanical loads are important to achieve a long the storage period (FAO, 2003).

Store room temperature, relative humidity, and atmospheric composition affect the length of storage that can be a achieved (FAO, 2003).

2.3.1. Storage losses:

2.3.1.1. Physiological losses (weight, sprouting, rotting and rooting):

In tropical and subtropical regions, losses of quantities and quality in onion bulbs are of the greater concern; the losses caused during storage may be due to sprouting, rotting, rooting and shrinkage. Proper storage is crucial for retaining bulb quality (Bhattarai and Subedi 1998, Biswas *et al*., 2010 and Doug, 2004).

Temperatures and relative humidity had been found to be correlated with sprouting, rotting, rooting, physiological losses in weight and storage period (Biswas *et al*., 2014), water loss through the neck of the bulbs is also a significant factor affecting onion storage (Rajapakse *et al*., 1992).

Moisture (weight) loss from onion bulb is greater at room temperature more than 27 ºC; Tanaka, 1991 and Yoo *et al*., 1989 and Tekeste *et al*., 2017, found that physiological weight loss of onion bulbs is increased from 3.39% at 2 weeks of storage to 21.47% at 12 weeks of storage period.

Likewise, onion bulb rotting is increased with progress of storage. The rotted bulbs percentage increased from 1.27% after six weeks storage to 11.45% after six weeks of storage (Tekeste *et al*., 2017)

Kukanoor, (2005), reported that sprouting caused shriveling of bulbs, consequently lowering marketable quality. Higher respiration rate with heat generation enhances re-growth of onion during storage causing moisture loss from bulb and reduces shelf life (Sohany *et al*., 2016), whereas Patil *et al*., (1986), indicated that maximum bulb sprouting losses were noticed at lower temperatures and high humidity during August to November. Tekeste *et al*., (2017), found that there was a progressive increase in sprouting of onion bulbs with advancement of storage duration increasing from 1.6% at 6 weeks after storage to 14.1 % at 12 weeks of storage.

Postharvest losses reach 40% of total production due to sprouting, decay, rooting and weight loss (Jahnzab and Nabi, 2005). Storage losses reached 43.9% of onion with different storage methods without curing of the bulbs and 31.9% even after curing over the storage period of 4 months (Bhattarai and Subedi 1998). Also Maini and Chakrabarti, (2000), found that the losses, where no bottom ventilation is provided, are estimated to the extent of 30 to 35 percent, 10 to 12 percent by rotting and 8 to 12 percent on an account of sprouting, depending upon the relative humidity and temperature during the rainy season. In Sudan, harvest and post-harvest losses can reach up to 40-60% (Mohammedali, 2009).

Onion bulbs can be stored in the ambient temperature in well aerated room up to October without or with minimum weight loss. After October, bulbs started to sprout, outer scales become dry and rapidly losses weight but can survive up to February in normal room temperature. After February the bulbs become totally dry and sprout dried because there was no additional nutrient or water for surviving the newly emerged shoots (Kopsell and Randle, 1997).

2.3.2. Storage Diseases:

Alliums are susceptible to several pathogens that cause bulb rotting in the field or in storage, caused by a number of pathogens that belong to genera *Aspergillus, Botrytis, Colletotlium, Erwinia, Fusarium, Lactobacillus,Penicillium, Pseudomonas* and *Rhizopu*.

In warm storage conditions, the rate of deterioration due to pathogens usually outweighs the importance of sprouting (Currah and Proctor, 1990). Hot and humid storage conditions are conducive for the growth of black mold (*Aspergillus niger*). Tanaka 1991 and Yoo *et al*., 1989, bacteria soft rot (*Pseudomonas gladioli*) (Wall and Corgan 1994 and Wright 1993) as well as other storage diseases of onion bulbs.

2.3.3. Storage economics:

Long storage life of onion bulbs without having much loss in terms of weight and other quality parameters like rotting and sprouting are the most important aspect for obtaining remunerative price and exports. It is so essential because onion is used throughout the year in various ways.

Storage affords producers access to future market prices and income, reduce price fluctuations, market speculation and improve competition and price stability (Jaanzab and Nabi, 2005). Farmers are compelled to sell their product at minimum prices at harvesting time, whereas there is an increased price and scarcity of dry onion bulbs from September onwards in the markets (Bhattarai and Subedi 1998). High storage losses compel onion producers to sell their produce immediately after harvest when the prices are low (Lemma and Shimelis, 2003), sometimes it becomes very difficult to cover the production costs. Considering the low onion prices at harvest time and its higher prices later, it is essential to select proper storage methods.

2.3.4. Effects of fertilizers on bulbs storability:

Farmers sometimes apply excess amounts of fertilizers targeting only for higher bulb yield, but they do not consider postharvest effects of fertilizers (Benti, 2017).

Growing the crop with chemical fertilizers may further increase the storage losses of onions. Potassium and sulphur have been considered good sources of nutrients for increasing the yield, storability and quality of onion. The organic manure like sheep manure and FYM are also cheap and good sources of nutrients for onion. It is known that the organic manure along with chemical fertilizers increase yield and quality; in view of the longer shelf life of the onion.

Many researchers (Chung, 1989; Komochi, 1990; Sorensen and Grevsen, 2001and Nabi *et al*., 2010) emphasized the need for optimizing fertilizers in improving post-harvest quality and storability of onions.

Tekeste *et al*., 2017, found that fertilizer application affected physiological weight loss, sprouting and rotting of onion bulb during storage period, minimum loss percentage, sprouting and rotting were observed with the control, whereas the highest losses, sprouting and rooting were reported with the highest doses of fertilizers.

Onion growers believe that excessive nitrogen prevents proper maturity and result in bulbs with poor storage quality (Sheikh *et al*., 1987), Heavy nitrogen applications during growth or nitrogen applied during bulb maturation decreased the storage duration (Gamiely *et al*., 1991and Uzo and Currah, 1990).

Singh and Dankhar, (1991) and Patel and Vachhani (1994), found that slight rapid deterioration was observed in treatments when maximum nitrogen (175 kg/ha) was applied. Moreover, higher risks of bulb storage losses were observed with high nitrogen levels that promote sprouting and decay.

NPK (15:15:15) at the rate (0, 120 and 240 kg NPK/ha) did not significantly retard deterioration in onion bulb quality aspects throughout six months storage (Elhag 2012)

Low soil sulfur levels might cause increased bulb rot (Brown and Leclaire-Conway, 2014).

2.3.5. Onion cultivars storability:

The ability of bulb storage is a cultivar- specific genetic trait relevant to the duration of bulb integrity, after harvest and curing, before sprouting and/ or rotting, water loss, or disease susceptibility (Corgan and Kedar, 1990, Maude, 1990, Sekara *et al*., 2017). Consumers have long since utilized the storage attributes of onion bulbs and have selected varieties based on their storability (Hanelt, 1990).

Onions that store well are generally long-day (LD) cultivars which often, but not always of long dormancy period, small bulb neck, low water loss and high dry matter. Poor storing onions are generally short-day (SD) cultivars which often, but not always of short-dormancy period, large bulb neck, high water loss after harvest and low dry matter (Woodman and Barnell, 1937, Gubb and Tavish, 2002 and Suzuki and Cutcliff, 1989). Short day onions are adapted to lower latitudes, they typically do not have to contend with long overwintering periods. Therefore, they tend to have short periods of dormancy and would often break dormancy quickly if stored at higher temperatures (Miedema 1994).

Locally adapted onion cultivars were selected over many years within the tropics and they tend to store better than the short day cultivars imported from external sources. Cultivars suitable for storage should produce a number of outer dry scales or skins, these outer skins help to create an effective vapour barrier around the bulb, thereby minimizing moisture loss, and also provide a physical and chemically resistant barrier to the entry of pathogens. Cultivars with several layers of skins are preferred (Brice, *et al*., 1997and Brice, *et al*., 1995).

Most of the Sudanese onion cultivars whether released cultivars like Saggai Improved, Kamleen, Elhilo and Baftaim(S), or landraces cultivars such Abu-Freaiwa are characterized by high dry matter percentages (≥ 15%) , pungent, with high total soluble solids and high storability, they can store up to 5-6 months in traditional stores. Whereas the American variety Texas Early Yellow Grano with low pungency, low dry matter (≤10%) is of low storability, losses about 50% from original weight during one month after harvest may reach 100% after two month in traditional store (Mohammedali, 2009).

Onion pungency changes during storage have been associated with the breaking of bulb dormancy. Although, flavor precursor concentration increased during storage, concentration decreased as bulb broke dormancy and sprouted (Lancaster and Shaw, 1991). Loss of dormancy, as indicated by root sprouting, differs among cultivars. All short day cultivars break dormancy within 4 month of storage, while long day cultivars could remain dormant for 6 month of storage.

In tropical regions research was done to evaluate cultivar storability. In Niger local varieties stored at ambient temperatures lost less than 20% of their original weight after six months compared with imported cultivars that had weight losses of 65-70% after only three months (Nabos, 1976). Also in Eastern Ethiopia, Benti (2017) evaluated three dominantly cultivated improved onion cultivars, found significant differences among the cultivars in rotting and sprouting. However rotted bulbs were not found until 60 days of storage for the varieties.

In recent studies in the Sudan, Ahmed, *et al*., (2014) evaluated the storability of two onion cultivars Baftaim (S) and Texas Early Yellow Grano; they found that physiological losses in traditional store were significant between the two cultivars; cultivar Baftaim (S) gave lower fresh weight loss of about 50% after 4 months. Whereas cultivar Texas Early Yellow Grano reached 100% loss in the second month, with the bulbs completely rotted, while cultivar Baftaim (S) recorded 6% rotting after 6 month storage. Cultivar Baftaim (S) in traditional stores did not sprout for 6 month storage, while cultivar Baftaim (S) showed significantly higher rotting percentage during storage than Abu-Freaiwa (Elhag, 2012).

Onion Breeding Program studies during 2004/07, indicated that the genotypes; Elhilo, Abu-Freaiwa and Baftaim (S), could be stored successfully under traditional storage structures up to six months, with a maximum loss of ± 20% largely due to shrinkage and to lesser extend to rotting (Mohamedali, 2007).

Abu-Bakr, *et al*., (2001) reported that the Sudanese onion local cultivars had the best keeping quality and storability, they store well for 6 months, and next were the Indian cultivars store for 4 months, and the American hybrid cultivars had least keeping quality and storability. The mean monthly percent increase in weight loss for local cultivars was 8.6 in the second month of storage (July), 7.8 in August, 20.6 in September and 24.2 in October. The American and hybrid cultivars sprouted with relatively higher percentage during the first month of storage, no sprouting was observed in local and Indian cultivars during the first month of storage, and the percentage remained low during the second month. Also local cultivars had the least mean average monthly rotting percentages, while all American and most of the hybrid cultivars had extremely high rooting percentages

Disease susceptibility is related to onion pungency, with sweet onions being particularly susceptible (Brown and Leclaire-Conway, 2014).

2.3.6. Other factors:

In dry seasons, supplemental `irrigation increased storage duration (Drinkwater and Janes, 1955); however, high irrigation levels just prior to harvest increased storage losses (Uzo and Curah, 1990)

Cutting roots too soon at harvest or breaking the neck prior to physiological maturity decreased bulb storage duration (Jones and Mann, 1963). Harvest as related to physiological maturity also influenced bulb storage duration. Harvesting onion when the foliage had lodged 50% to 80% of the plants resulted in the longest bulb storage (Komochi, 1990).Leaving the bulb in the field after foliar lodging also decreased bulb storage life and quality (Tucker and Drew, 1982). Likewise, bulbs cured for 3 days at 37Cº and 37% relative humidity (RH) stored longer with better quality than did uncured bulbs (Komochi, 1990)

CHAPTER THREE

MATERIALS AND METHODS

3.2. Onion bulbs storability:

3.2.1. Location:

The storage experiments were carried out from July to November for two seasons in 2015 /16 and 2016/17 in the onion store of the Horticultural Crops Research Center at Shambat Research Station , Agricultural Research Corporation , Sudan , Khartoum North (Lat. 15° ٤٠" N and long . 32° 32"E . and 281m. above sea level).

In the first season the mean maximum and minimum temperature during the storage period 37.2 and 23.3c°, respectively, and 43.7% average relative humidity, rainfall of 165 mm, while in the second season the mean maximum and minimum temperature were 37.3 and 23.5 c°, relative humidity average 38.3%, and average rainfall 42.9 mm. (Annex 2).

3.2.2. Store structure:

The store is a traditional open structure; the direction is east – West
(8 m×4 m = 32 m²), the floor level 0.7 -1.0 m above ground to avoid flooding and to provide good aeration.

3.2.3. Preparation of bulbs for storage:

The harvested bulbs were cured (10-15 days), and then cutting the foliage (leaves) 2 cm from the neck. Cured bulbs were sorted to sound (single bulbs). Double, bolted, off-type, injured and defected bulbs were discarded and only the sound bulbs were selected for storage experiments.

3.2.4. Onion storage:

Five kilograms random sample of sound bulbs were selected from each treatment packed in a plastic netted sacks and replicated three times. The storage experiments started in July in the two seasons.

3.2.5. Data collected:

The following parameters were recorded monthly:

1- Rotted bulbs (weight).
2- Sprouted bulbs (weight).
3- Infected bulbs with black mold (weight).
4- Total weight loss.

The stored bulbs were removed; sorted and the different categories weighed and then healthy bulbs returned to the sacks, the losses were recorded as percentages.

3.2.6. Experimental design and Statistical analysis:

The treatments were arranged in completely randomized design (CRD) with three replications. The data were analyzed using GenStat (Computer Program) Version 4 and the means were separated using Duncans Multiple Range Test (DMRT) at $P \leq 0.05$ (Gomez and Gomez, 1984).

CHAPTER FOUR

Results

Storage data collected for five onion cultivars reflected variations in their storability, as indicated by the parameters used:

4.2.1. Total weight loss percentages:

This data include weight loss, rotted bulbs, sprouted bulbs and infected bulbs by black mold.

Data shown in Fig. 1 onion cultivars differed in total weight loss percentages, cultivar Texas Early Yellow Grano with the highest total loss percentages of 36-32 and 39-35 % in the first month, Baftaim (S) the lowest in the first and second seasons with 15 % and 25%, whereas Kamleen and Saggai Improved recorded 17 % and 25 % the highest percentage among the local cultivars in the first and second month of storage. In the third and fourth months the local cultivars Saggai Improved and Abu-Freaiwa recorded 27 % being the lowest loss percentage, while cultivar Kamleen recorded the highest loss percentage in the last two months of storage (30 and 32 %).

The overall average percentages of total loss in the first month were 20 % it increased to 29 % in the last month of the storage period (Fig.32).

4.2.2. Rotted bulbs percentage:

Fig. 3 shows the differences among onion cultivars, the highest percentages of rotting was recorded by the cultivar Texas Early Yellow Grano 3 % and 4 %, whereas the lowest percentages of rotted bulbs 1 and 2 % recorded for Baftaim (S)

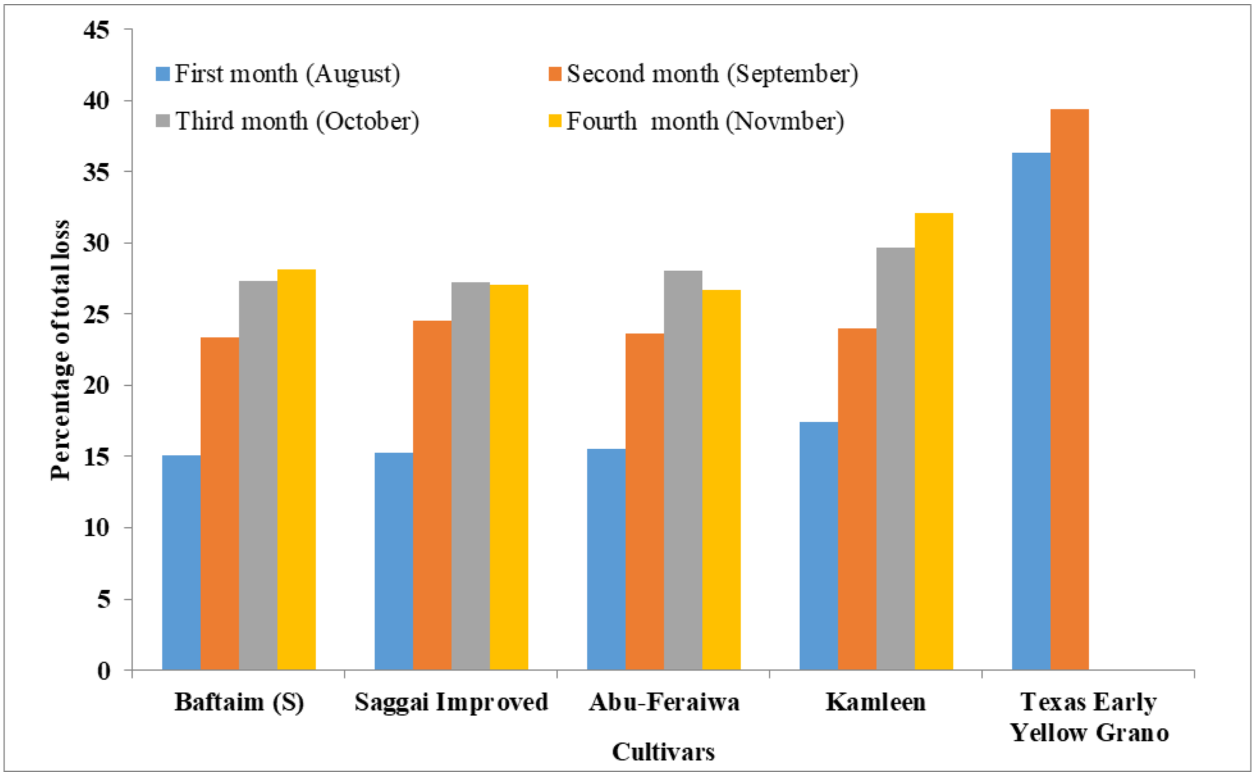

Fig. (1): Total loss percentages of five onion cultivars during 2015/16 and 2016/17, seasons.

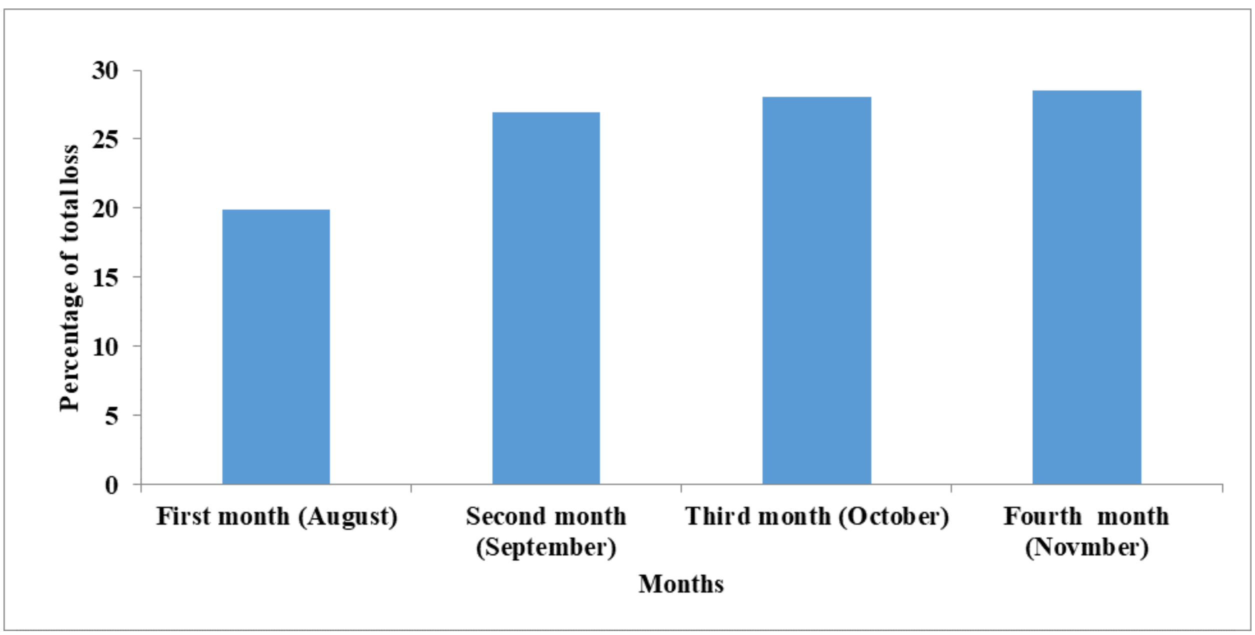

Fig. (2): Total loss percentages during storage period of five onion cultivars during 2015/16 and 2016/17, seasons.

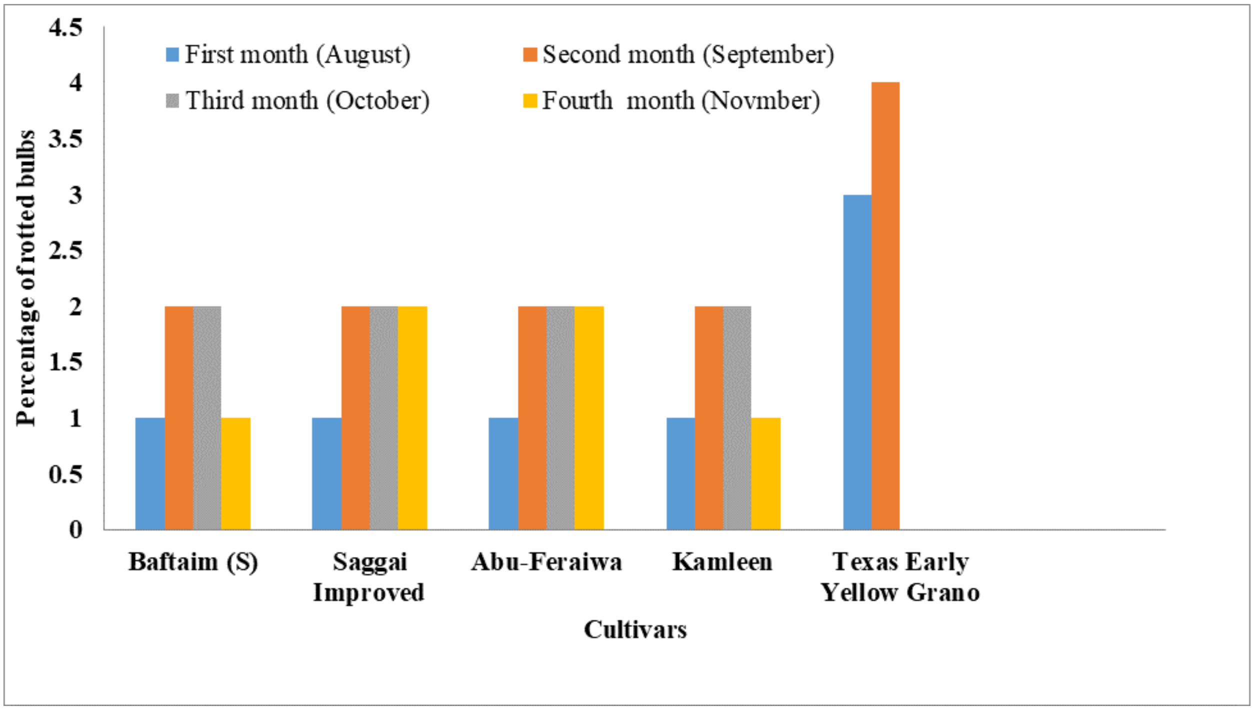

Fig. (3): Rotted bulbs percentages of five onion cultivars during 2015/16 and 2016/17, seasons.

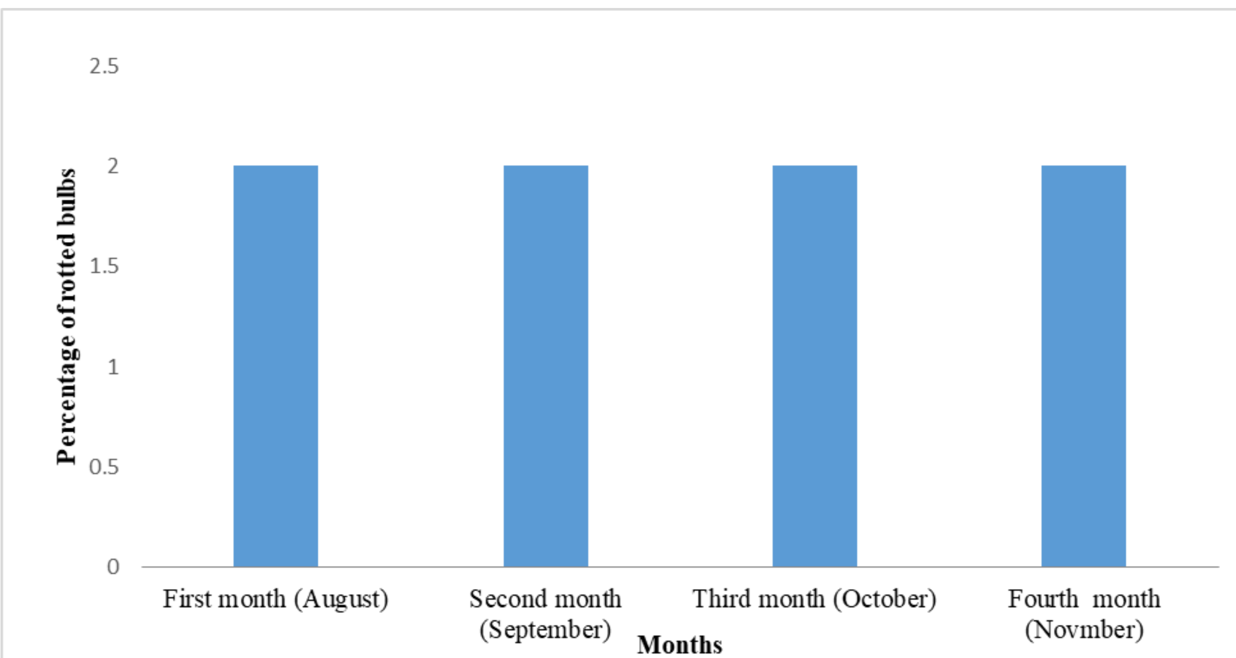

Fig. (4): Rotted bulbs percentages during storage period of five onion cultivars during 2015/16 and 2016/17, seasons.

in the first and second month, respectively. In the third and fourth month the local cultivar Kamleen gave 2 and 1 % which the lowest percentage of rotted bulbs and the highest percentage recorded by the cultivar Abu-Freaiwa (2 %).

The lowest percentages of rotted bulbs 1 % in the last month of storage, whereas the highest percentages observed in the second month 2 % (Fig. 4).

4.2.3. Sprouted bulbs percentages:

The introduced cultivar Texas Early Yellow Grano recorded the highest percentages of sprouted bulbs of 1 and 2 % in the first and second month, while the cultivar Saggai Improved gave the highest percentages in the third and fourth months of 2 %. The cultivar Baftaim (S) gave the lowest percentages of sprouted bulbs during the storage period recording 1%. The percentages of sprouting in all cultivars increased with the increase of storage period (Fig. 5).

As in Fig. 6 the lowest sprouted bulbs percentage of 1 % in the first month increased during storage period to reach 2 % in the fourth month of storage.

4.2.4. Infected bulbs by black mold (*Aspergillus niger*):

As shown in Fig. 7 cultivar Texas Early Yellow Grano had the lowest infested bulbs (1 %) in the first month, while the lower percentage recorded by cultivar Abu-Feraiwa (1 %) in the second month and cultivar Baftaim (S) gave 2 % in the third and fourth month. Cultivar Kamleen recorded percentages of infected bulbs in all four months of storage as 2, 2, 3 and 2 %, respectively.

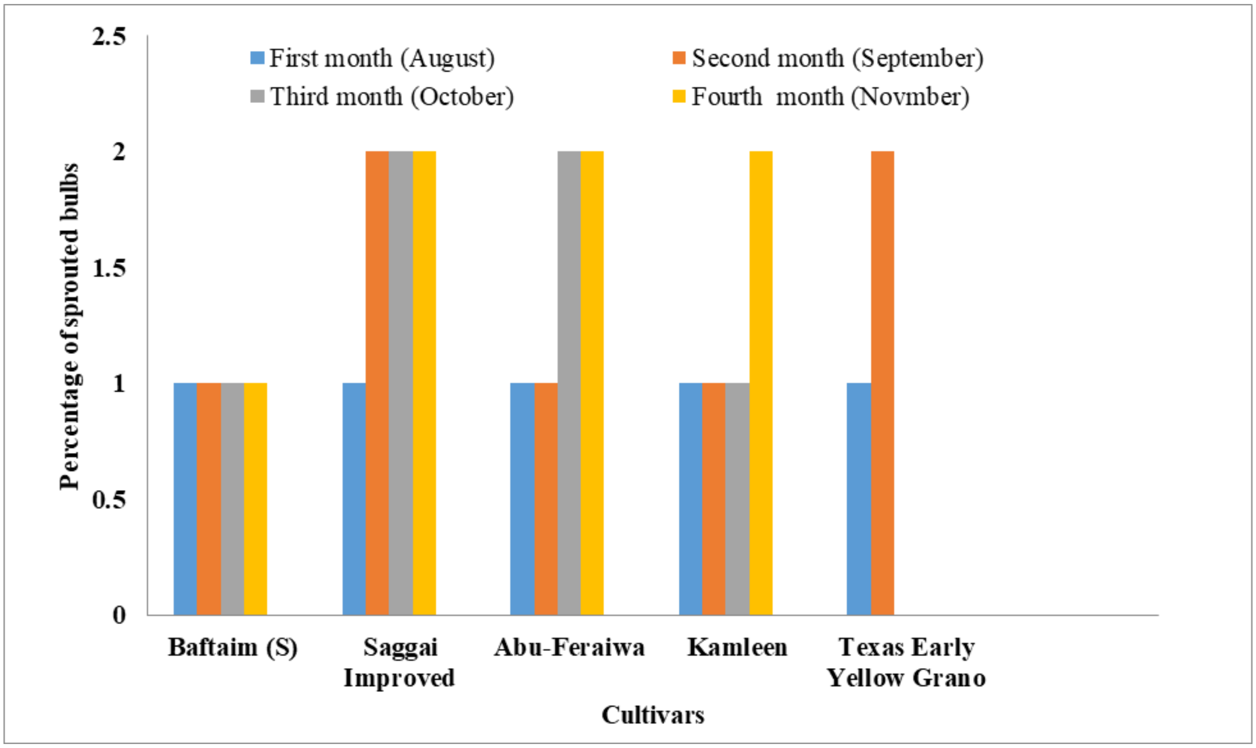

Fig. (5): Sprouted bulbs percentages of five onion cultivars during 2015/16 and 2016/17, seasons.

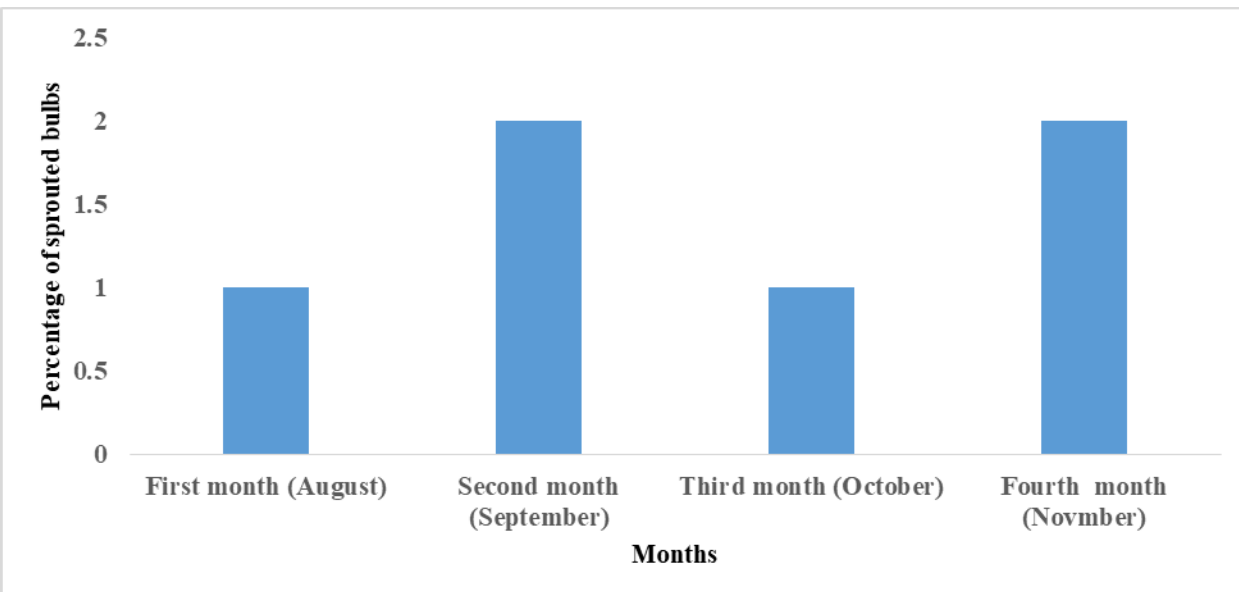

Fig. (6): Sprouted bulbs percentages during storage period of some five onion cultivars during 2015/16 and 2016/17, seasons.

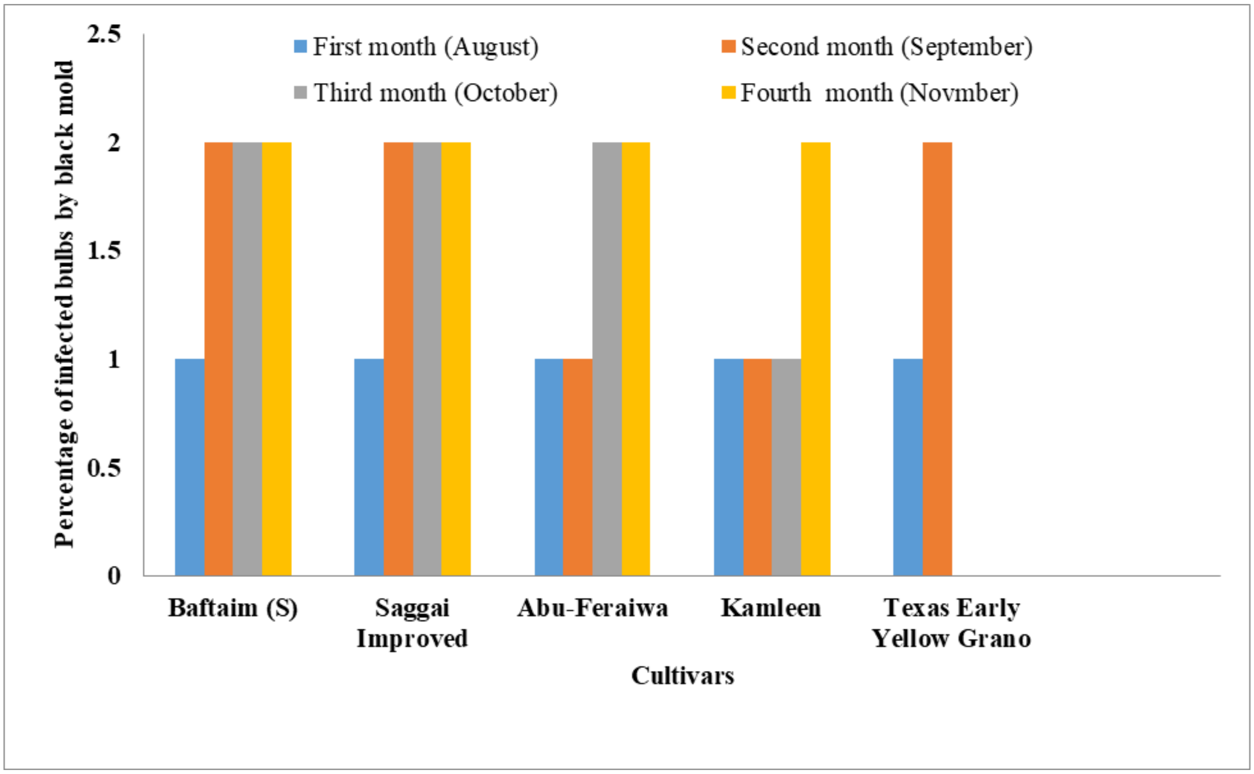

Fig . (7): Percentages of Infected bulbs with black mold of five onion cultivar during 2015/16 and 2016/17, seasons.

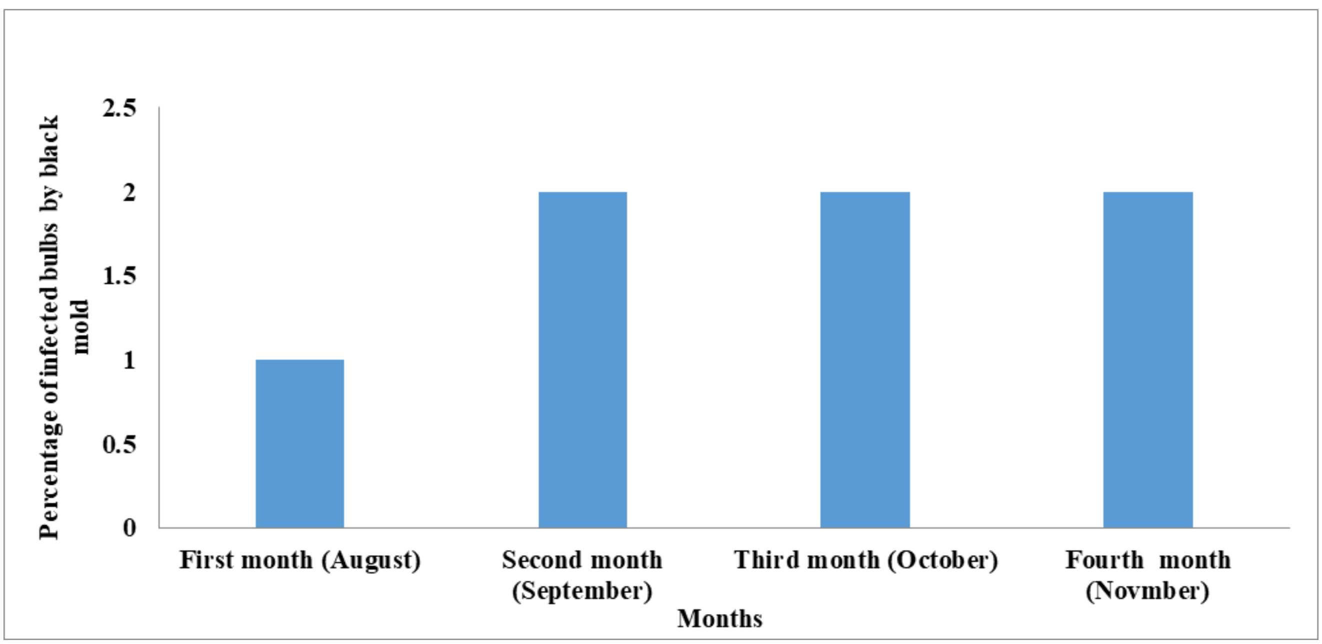

Fig. (8): Percentages of infected bulbs by black mold during the storage period of five onion cultivar during 2015/16 and 2016/17, seasons.

CHAPTER FIVE

DISCUSSION

Onion Bulbs storability:

The results in this study showed marked differences among the five cultivars in storability.

Rotting, sprouting, weight loss and black mold infection were considered the most important parameters to evaluate onion cultivars storability in traditional stores in Sudan.

The introduced cultivar Texas Early Yellow Grano was the highest in rotting, sprouting, infected bulbs by black mold and total weight lost; it loss more than 30% in the first month (July), the total loss reach100% after two months in a traditional store. Cultivar Texas Early Yellow Grano yielded higher than local cultivars with low total soluble solids and dry matter content. Cultivar Baftaim (S) out yielded the local cultivars moderate total soluble solids and high dry matter content, the cultivar Baftaim (S) the lowest rotting, infected bulbs by black mold and total loss in the beginning of storage period (first and second months (July and August)) and increased with increased storage period and then increased, whereas it had the lowest percentage of sprouting during the storage period.

The variations in storability among onion cultivars were also reported by Corgan and Kedar (1990), Maude (1990) and Sekara *et al.*, (2017), they suggested that the ability of bulbs storage capacity is a cultivar-specific genetic trait.

Woodman and Barnell (1937), Gubb and Tavish (2002), Suzuki and Cutcliff (1989) and Miedema (1994), reported that long day cultivars which often have long dormancy period and high storability, small bulb neck, low water loss and high dry matter are of good storability. Whereas, poor storing onions are generally short day cultivars which often (but not always) of short dormancy period (which is break dormancy quickly broken if stored at high temperatures), large bulb neck, high water loss after harvest and low dry matter. Brice *et al*., (1997), reported that locally adapted onion cultivars were selected over many years within the tropics and they tend to have better storability than the short day cultivars imported from external sources. Local Sudanese onion cultivars store better than the introduced cultivars Texas Early Yellow Grano, this results was confirmed by (Mohamedali 2009), who stated that most of the Sudanese onion cultivars characterized by high dry matter content, pungent with high total soluble solids and high storability, they can be store up to 5-6 months in traditional stores, whereas the American cultivar Texas Early Yellow Grano with low pungency, low dry matter content is of poor storability, it lost about 50% from original weight during one month after harvest and could reach 100% after two months in traditional stores. Mohamedali (2007), also reported that Elhilo, Abu-Freiawa and Baftaim (S) could be stored successfully under traditional storage structures up to six months. The finding agree with Abu-Baker, *et al*., (2001), who reported that the Sudanese onion local cultivars had the best keeping quality and storability. They could be well stored for six months. The next were the Indian cultivars which could be stored for four months. The American and hybrid cultivars had the least keeping quality and storability. The mean monthly percent increase in weight loss for local cultivars was in 7.8 in July and 24.2 in October. The American and hybrid cultivars sprouted with relatively higher percentage during the first month of storage, whereas no sprouting was observed in local cultivars during the first month of storage and remained low during the second months.

General Conclusions

I. Vegetable growth: evaluated using parameters; plant height, number of leaves per plant and leaf length, indicated in most cases in the two seasons, the absence of significant differences among the different fertilizers regimes used. As for cultivars, Baftaim (S) and Kamleen proved to have ample vegetable growth according to the three parameters used, whereas Texas Early Yellow Grano has sparse vegetable growth.

The highest total and marketable yields were recorded for Baftaim (S) and Texas Early Yellow Grano. This could be explained that yield capacity depends on the capacity of a genotype to how much it could potion from the biological yield (vegetable growth) to the sink (bulb) i.e. economic yield.

Lack of cultivar – fertilizer interaction could be attained to the cultivar genetic make-up and/or the levels and type of fertilizers used in the study or possibly the experimental sites.

II. Quality characters: the quality characters evaluated, doubled bulbs, bolters, bulb weight, diameter, length, neck diameter, number of storage leaves (rings), total soluble solids (TSS) and dry matter, all were significantly affected by fertilizers treatments. Variations among cultivars for the above traits were significant, an indication that the above variations are cultivar characters i.e. genetically and consequently, cultivar – fertilizer interaction is non significant as fertilizers differences were non significant.

III. Cultivars storability: the storage capability of the five cultivars was assessed using the parameters; rotting, sprouting, weight loss and disease infection.

As mentioned in the text, storability of onion cultivars is positively correlated with pungency, total soluble solids and dry matter. The three characters are genetically controlled. Other environmental factors include management practices and the storage environment particularly temperature and relative humidity.

The results indicated that all four Sudanese cultivars; Kamleen, Saggai Improved, Baftaim (S) and Abu-Feraiwa were kept satisfactory for four months (August – November) in the traditional open-shed store at ambient temperatures and relative humidity. The cultivar Texas Early Yellow Grano, an introduced mild, low dry matter and total soluble solids stored only for 2-4 weeks.

IV. It could be concluded that more precise and defined research is needed in Sudan to assess the commercially planted cultivars and their response to various type of fertilizers currently used without scientific recommendation. The research should consider different onion cropping systems and fertilizers.

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Annexes

Annex (1): Analysis of field soils at different depth:

Depth	pH paste	ECe	Soluble Cations Meq /L			SAR	Soluble Anion Meq /L		
			Na	K	Ca+ Mg		CO3	HCO3	CI
0-30	7.8	0.88	4.5	0.3	4.0	3	0.0	1.2	0.6
30-60	7.9	0.79	4.6	0.3	3.1	4	0.0	1.3	0.6

Depth	O.C %	N %	P ppm	Ex. Ch.Cations Meq /100g			CEC Meq/100g	ESP	CaCo3	Texture%			Saturation %
				Na	K	Ca+Mg				Clay	Silt	Sand	
0-30	0.4	.0.05	8	12.3	2.3	42.4	57	22	4	53	19	28	65
30-60	-	-	-	15.8	1.8	32.4	50	32	5	61	17	22	67

Soil laboratory, College of Agricultural Studies, Sudan University of Science and Technology.

Annex (2): Monthly mean maximum and minimum air temperature (°C), relative humidity (%) and rainfall at Shambat during growing seasons November 2015 - December 2017

Months	**2015/2016**				**2016/2017**			
	Mean temperature (cº)		Relative humidity (%)	Rain fall (M M)	Mean Temperature (cº)		Relative humidity (%)	Rain fall (M M)
	Max.	Min.			Max.	Min.		
November	34.1	20.5	27	0.0	36.0	21.4	31	0.0
December	28.7	14.2	31	0.0	33.4	17.5	34	0.0
January	30.4	12.6	32	0.0	34.2	16.7	30	0.0
February	33.3	15.7	29	0.0	31.6	14.9	23	0.0
March	38.9	19.2	21	0.0	36.6	17.6	18	0.0
April	40.9	21.4	19	0.0	40.9	24	17	TR
May	42.8	26.0	24	1.0	41.6	26.3	28	5.3
June	41.5	26.2	31	TR	42.4	26.4	30	1.5
July	37.9	25.6	47	72.5	39.9	26.5	42	40.4
August	36.1	25.2	55	69.5	36.6	24.8	52	0.0
September	39.2	25.2	63	23.0	39.3	26.5	42	2.5
October	40.2	24.6	32	TR	39.4	24.3	27	0.0
				November	34.8	20.8	30	0.0
				December	33.5	18.3	37	0.0

Source: Ministry of Environment, Forestry and Physical Development Meteorological Authority Weather – climate data.

Shambat Metrological Station.

Annex (3): Compost Elshmokh Analysis:

Humidity	31
Ph	7.65
ECe	1.7
Ca%	4
Pass Particale 2mm	53.27
Mg%	3
Na%	3
K%	5.27
P%	2.05
O.C%	26
O.M%	44.7
N%	1.4
C/N	18.8
Cu ppm	0.536
Fe ppm	149.725
Mn ppm	4.953
S ppm	141.773

Data source: Project of Shomokh Eltabya. Organic fertilizer factory.

Annex (4): Treatments:

Number	Treatments
1	Control (without fertilizer) + Baftaim (S).
2	Control (without fertilizer) + Saggai lmproved.
3	Control (without fertilizer) + Abu– Feraiwa.
4	Control (without fertilizer) + Kamleen.
5	Control (without fertilizer) + Texas Early Yellow Grano.
6	Urea + Baftaim(S).
7	Urea + Saggai lmproved.
8	Urea + Abu– Freaiwa.
9	Urea + Kamleen.
10	Urea + Texas Early Yellow Grano.
11	Organic (Elshmokh) + Baftaim (S).
12	Organic (Elshmokh) + Saggai lmproved
13	Organic (Elshmokh) + Abu– Freaiwa.
14	Organic (Elshmokh) + Kamleen.
15	Organic (Elshmokh) + Texas Early Yellow Grano.
16	NPK + Baftaim (S).
17	NPK + Saggai lmproved
18	NPK + Abu– Freaiwa.
19	NPK + Kamleen.
20	NPK + Texas Early Yellow Grano.
21	Ammonium sulphate + Baftaim (S).
22	Ammonium sulphate + Saggai lmproved
23	Ammonium sulphate + Abu– Freaiwa.
24	Ammonium sulphate + Kamleen.
25	Ammonium sulphate + Texas Early Yellow Grano.