Effects of Sowing Date and Nitrogen Rate on Yield and Storability of some Onion (*Allium cepa* L.) Cultivars in the River Nile State, Sudan

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Dedication

To

My beloved

Mother... and... Father

Hassan

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First of all, I would like to thank Almighty God (Allah) for everything.

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Hassan Abdalmotalib Haj Ahmed Elamin

Abstract

Onion is one of the most important vegetable crops in the Sudan. Cultural practices such as sowing date and fertilization are crucial factors for onion production and storability in the River Nile State. Therefore, the objective of this study was to determine the effects of sowing date and nitrogen rate on yield and storability of selected onion cultivars. Experiments were carried out at Shendi Research Station farm during two consecutive seasons of 2014/15 and 2015/16. Treatments consisted of three sowing dates, which were first of December, first of January and first of February. Nitrogen rates were 0, 43 and 86 kg N /ha and the cultivars were Baftaim and Abuferwa. Treatments were arranged in a split plot design with three replicates. Results showed that the first of December sowing date and application of nitrogen at 86 kg N/ha significantly resulted in the most vigorous vegetative growth and the highest total yield in both seasons. The cultivar Baftaim had more vigorous vegetative growth, large bulb size and total yield than the local cultivar Abufrewa in both seasons. However, Abufrewa cultivar had higher dry matter content and better storability than Baftaim. Early transplanting of onion in the first of December resulted in higher postharvest losses than late transplanting in both seasons. It is recommended to transplant Baftaim cultivar in the first of December and apply 86 kg N/ha to obtain the highest yields.

تأثير تاريخ الزراعة ومعدل النيتروجين علي الإنتاجية والمقدرة التخزينية لبعض أصناف البصل (*Allium cepa* L.) بولاية نهر النيل، السودان

حسن عبد المطلب حاج احمد الامين

ملخص الدراسة

يعتبر البصل من اهم محاصيل الخضر فى السودان. المعاملات الفلاحية مثل تاريخ الزراعة والتسميد تعتبر من العوامل الهامة جدا فى انتاج البصل فى ولاية نهر النيل. هدفت الدراسة إلي معرفة تأثير تاريخ الزراعة ومعدل إضافة سماد النيتروجين علي الإنتاجية والقدرة التخزينية لبعض أصناف البصل. أجريت هذه التجربة بالمزراعة التجريبية بمحطة بحوث شندي– نهرالنيل في الموسمين (2014/15–2015/16).
اشتملت المعاملات علي ثلاثة تواريخ للزراعة وكانت الأول من ديسمبر والأول من يناير والأول من فبراير و ثلاثة معدلات من النيتروجين وهى صفر و43 و86 كيلوجرام للهكتار مع صنفين من البصل وهى بافطيم و ابوفريوة. استخدام تصميم القطع المنشقة بثلاثة مكررات. أظهرت النتائج أن زراعة البصل فى الأول من ديسمبر مع معدل النيتروجين 86 كيلوجرام /هكتار أعطي افضل نمو خضري وأعلى أنتاجية في كلا الموسمين. الصنف بافطيم أعطى أفضل نمو خضري وأكبر حجم للأبصال وأعلي إنتاجيه مقارنة مع الصنف أبوفريوة في كلا الموسمين. لكن الصنف أبوفريوة أعطي أعلي نسبه من المادة الجافة وافضل قدرة تخزينية مقارنة بالصنف بافطيم. زراعة البصل مبكرا فى الاول من ديسمبر أعطت أعلى فاقد ما بعد الحصاد بالمقارنة مع الزراعة المتأخرة فى كلا الموسمين. استناداً على هذه النتائج نوصي بزراعة الصنف بافطيم في الأول من ديسمبر مع إضافة 86 كيلو جرام نيتروجين/هكتار للحصول على أعلى إنتاجية.

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CHAPTER ONE
INTRODUCTION

1.1 General introduction

Onion (*Allium cepa* L.) is the second most important vegetable crop after tomatoes (Griffiths *et al*., 2002), with a world production of about 64.5MT. Onion production is increasing annually in terms of tonnage with fluctuations in price, which is due to the seasonality of the crop. It is a profitable cash crop which encourages farmers to produce every year. Onion is the most important vegetable crop in the Sudan. Area of production is estimated at 25000 ha, annually, primarily as a winter crop for fresh consumption and dehydration. The River Nile, Gezira, and Kassala States are the main areas for production of winter onion, especially Shendi area as a late winter crop (Mohamed and Nouria, 1988). There have been efforts to export fresh onion to Arabian Gulf and West European countries during November – May.

1.2 Justification

Onion is a perishable commodity and difficult to store for long periods under ambient conditions, especially in tropical and sub- tropical countries. Storage plays a very important role in marketing of onion (Kukanoor, 2005). The aim of onion bulb storage is to cover consumer demands and extend its availability. The main factors which cause deterioration of onion bulbs during storage are pre- and post- harvest environmental conditions such as temperature and relative humidity (Fatideh and Pourasil, 2012).

1.3 Objectives

1.3.1 General objective

To increase the storage life and reduce the storage losses of onion.

1.3.2 Specific objectives

To determine the most appropriate sowing date for a long shelf life of onion in the River Nile State.

To investigate the effect of nitrogen fertilizer on yield and storability of onion.

To find out the most storable onion cultivar.

CHAPTER TWO
LITERATURE REVIEW

2.1 Origin and uses of onion

The common onion (*Allium cepa* L.) is a member of the family *Alliaceae* and one of the most important vegetable crops throughout the world.

Onion is one of the most ancient crops under cultivation dating back to at least 4000 BC. It was grown along the River Nile at the time of Egyptian Pharaohs and it was mentioned in the Bible and Holly Quran. The primary center of origin of onion lies in Central Asia (Vavilov, 1951; Hasegawa *et al*., 2001). The Near East and the Mediterranean are the secondary centers of origin (Mallor*et al.*, 2011).

World production increases annually due to the development of high yielding open pollinated and hybrid varieties, improved technologies of production, control of pests and diseases, harvesting, processing and storage facilities (Nabi *et al*., 2010). Onion is used in a variety of ways i.e. green onion in salad, cooked, pickled, powder or flakes. In the Sudan, it is the most popular vegetable and is an integral part of almost all Sudanese dishes all over the county (Alaodate *et al*., 1984).

Onion composition depends on a large number of factors, such as the genotype, growing conditions, time and length of harvest and conditions of storage (Watt and Merrill., 1963). It has been found that people who eat more onions had a much lower risk of developing stomach cancer leaf. Onion is used in traditional medicine for relieving toxicity and breaking down areas of infection like sores or abscesses (Christopher and John 2004).

2.2 Growth conditions

Onion is grown under a wide range of climatic conditions ranging from temperate to tropical. Under normal conditions, onion forms a bulb in the first season of growth and flowers in the second season. Initiation of bulb is controlled by day length which varies from 11to 16 hours depending on variety. Proper crop variety selection to adapt day length is essential. Growing long-day temperate variety in tropical zones with short days will produce only vegetative growth without forming a bulb (FAO, 2013). Bulb development in onion is promoted by long photoperiods and cool temperatures (Brewster, 2008).

Optimum soil temperature for germination is 15 to 25°C. The crop flourishes in mild climates without extremes in temperature and excessive rainfall. For the initial growth period, cool weather and adequate water are required for establishment, whereas during ripening, warm dry weather is beneficial for high yield of good bulb quality (Michael, 2007). The length of the growing period varies with cultivar and climate, but in general, it ranges between 130 to 175 days (FAO, 2013).

2.3 Factors affecting storability of onion

2.3.1 Biological factors

The main biological factors leading to the deterioration of onion bulb during storage are respiration, water loss and pathogen attack.

2.3.1.1 Respiration

Respiration rate of onion bulbs affects their storability. A low rate of respiration reflects high storage potential (Ryall and Pentzer, 1974). Respiration rate depends on the physiological state of the bulb (Benkeblia, 2000*)*. The respiration rate of a sprouted bulb is greater than that of non sprouted ones. The respiration rate of onion bulbs is lower than most vegetable crops (Jones and Mann, 1963). It declines immediately after harvest and the respiration rate of dormant onion bulbs is very low compared with freshly harvested bulbs (Thomas and Isenberg, 1972).

2.3.1.2 Water loss

Water accounts for 80-90% of the fresh weight of onions. The actual amount depends on cultivar and growing conditions (Gubb and Mac Tavish, 2002). Water loss is one of the main causes of bulb deterioration during storage. It leads to direct loss of marketable weight, limpness and a less acceptable appearance (Dorothy and Shipway, 1978). Water loss during curing and drying is rapid and around 5% of fresh weight and continues throughout storage because of evaporation (Gubb and Mac Tavish, 2002).

Water loss depends on many factors such as bulb maturity at harvest, time of harvest, moisture content of the bulbs, storage temperature and humidity, air movement and atmospheric pressure (Ryall and Lipton, 1979). Bulbs harvested early in the season lost most of their weight during storage, because of immaturity which resulted in high interior moisture content (Atwa *et al*., 1974). Sandhu *et al*. (1976) found that average losses in bulb weight during storage were 21.3% and 19.4% for white and red cultivars, respectively.

2.3.1.3 Pathogen attack

Post-harvest development of pathogens in onion is affected by temperature and relative humidity during storage (Kukanoor, 2005).

Onion storage diseases which cause large losses are infection by bacteria and fungi. The most destructive ones are gray mould rot (neck rot) caused by *Botrytis alli,* black mould rot caused by *Aspergillus niger,* Fusarium basal rot caused by *Fusarium* spp and bacterial-soft rot caused by *Erwinia carotovora* (Eltobshy *et al.,*1982). Storage of onion at a relative humidity of 85% encouraged the development of neck rot disease. Basal bulb rot disease increases with the increase in temperature up to 35°C and relative humidity up to 75% (Maude *et al.,* 1984). Abdelkarim (1986) studied onion losses in three local cultivars (Hilalia, Nasi and Kamleen) stored for six months in a cottage. He found that losses were mainly due to black mould disease caused by *A. niger* and they were 33%, 38% and 51% for Hilalia, Nasi and Kamleen, respectively. Heat treatment is a method used to control onion post- harvest diseases. Losses were found to be 15% after a storage period of 7 months when onions were heated to 45°C and storage in clamps with ventilation channels through which hot air was circulated (Peters and Maltry, 1979). Heat treatment of onion at 35-40°C for 6-10 hours significantly controlled neck rot disease and prevented sprouting in storage (Krotova and Malenkina, 1955). Post- harvest application of borax is recommended to minimize losses and sustain quality of onion in storage (Bose *et al.,* 2003).

2.3.2 Onion cultivars

Onion cultivars vary in their shape, outer skin color, storability, pungency, premature bolting and doubling (Purse-glove, 1972). Sudanese onion cultivars are the outcome of a long term selection process carried out by farmers in different locations. They are characterized by undesirable qualities particularly premature bolting, doubling, splitting, heterogeneity in color, size and shape in addition to susceptibility to pink root rot disease caused by the soil fungus *Pyrenochaeta terrestris* (Elhilo, 1976,Yassin *et al*., 1982) and onion yellow dwarf virus disease(OYDV). The recently released onion cultivars such as Saggai Improved, Elhilo and Kamleen Yellow are very popular and suitable for export. The red and reddish brown cultivars are high in dry matter content, pungent and keep well under traditional storage conditions (Mohamed, 1987).

2.3.3 Pre-harvest factors

Pre-harvest factors and conditions in the field affect storability of onion. These include nutrition, temperature during the growing season, application of growth regulators, bulb maturity at harvest and the harvesting process.

2.3.3.1 Nutrition

Application of fertilizers were found to influence the storability of onion bulbs, application of nitrogen without potassium tends to decrease the keeping quality (kunkel, 1947). Nitrogen deficiency also slightly reduced shelf –life (Sorensen and Grevsen, 2001) increasing rates of p fertilization increased number and thickness of dried out scales of onion and hence improved storage life (Knott, 1933). Singh and Kumar (1969) Stated that an increase in the rate of nitrogen from 44 to 112kg/ha resulted in an increase in rotting, sprouting and total weight loss when onion bulbs were stored at room temperature. Onions that are grown on soils with high organic matter have poor keeping quality than those are grown on lower organic matter soils due to the effects of organic soils in delaying bulb maturation through the retention of both nitrogen and soil moisture (Gutzman and Hayslip, 1962).

2.3.3.2 Application of growth regulators

In recent years, many growth substances have been used to delay sprouting in stored onions. Using the plant hormone (ethylene) or 1-methyl cyclo propane can inhibit sprouting in onion (Downes *et al*., 2010). Onion bulbs kept under N_2O for 5 days had less rotting than untreated bulbs (Benkeblia and Varoquaux, 2003). Pre - harvest application of ethephon increased the storage life of onion (Bufer, 2009).

Pre- harvest application of maleic hydrazide was used to inhibit sprouting of bulbs in storage (Johnson, 2006; Chope *et al*, 2006). It extended the marketing season from two to eight months (Kukanoor, 2005).

2.3.3.3. Bulb maturity at harvest

The developmental stage of onion at harvest has impacts on both yield and storage potential. The optimum harvest time for storage of onions is at 80%-90% tops down, sacrificing some yield for a greater number of intact skins (Gubb and MacTavish, 2002). If bulbs are harvested too soon, the water content in foliage leaves and the neck will be too high, which results in increased susceptibility to pathogen attack (Romanowski, 1962). Early harvested bulbs may not be dormant and would, therefore, be unsuitable for storage (Chope, 2006). Maturity stage at harvest can influence initial bulb weight, respiration, incidence of sprouting, decay and cumulative weight loss (Chope, 2006). Rutherford and Whittle (1982) found that bulbs harvested early, dried and stored in the same manner as bulbs harvested later, had lower carbohydrate levels and high incidence of sprouting.

2.3.3.4 Harvesting process

Physical injury to onion bulbs during harvesting must be minimized, especially for softer less pungent onions, because wounding increases storage losses due to rotting. Undercutting is usually performed prior to mechanized lifting. Aerial parts and roots are removed before onions are stored in bulk, which aids airflow between the bulbs (Chope, 2006). In temperate countries, the crop is then moved directly into a heated, forced-air ventilation store for immediate curing (Gubb and MacTavish, 2002).

2.3.4 Post harvest factors

Postharvest treatments and storage conditions have significant impact on the storage lifeof onion. These include curing, drying, irradiation, nitrous oxide treatment, temperature, gaseous composition of the atmosphere and relative humidity.

2.3.4.1 Curing and drying

The purpose of curing is to dry the thin outer layers of the bulb to form one or more complete outer skins which act as a barrier against water loss and infection by fungal pathogens such as *Botrytis allii*(neck rot), *A. niger* (black mould) and *F. oxysporum* (basal rot), and bacterial pathogens such as *E. carotovora* (soft rot) (Maude *et al*., 1984, Fenwick and Hanley, 1985). Onions for storage are cured and dried after harvest (O'Connor, 1979). The aims of curing onion are to encourage the development of natural dormancy, seal the neck and outer scales to reduce water loss, prevent diseases and to form intact dry over scales to reduce the respiration rate of bulbs (Waltz and Burr, 1977). Curing is complete when the necks have dried out and are tightly closed and the skins have an attractive colour (O'Connor, 1979). It is important that the skin integrity, firmness, colour and flavor are maintained during curing (Chope, 2006). The curing period normally takes about 6-14 days under natural conditions (Matson *et al*., 1978).In stores it depends on the temperature and relative humidity of the forced ventilation air and the maturity stage of the bulbs (chope, 2006). Optimum temperature for curing is 24-32 ºC for 2-3 weeks with a relative humidity of 50-70% (Jones and Mann, 1963). The standard practice is to dry the bulbs in bulk stores using air at 30ºC. After three to five days, the temperature is lowered to 24ºC and relative humidity to 70 - 75% to complete the curing process. The crop is then slowly cooled to the desired storage temperature (Chope, 2006). Blowing heated air at 40ºC and 3.35m^3/min for a period of 72 hrs provides satisfactory curing which was associated with the highest storability of bulbs (Abdelrahman, 2004). The lowest percentage of loss due to sprouting and physiological loss in weight was obtained with curing under the sun with foliage (Pandey *et al*., 1992). Curing is essential to obtain maximum storage life and minimal decay. Warm temperature, low relative humidity and strong air flow are conditions needed for efficient curing (Grahame, 2005, Marita, 2006). The most commonly used method of curing involves blowing heated air at 35-45 ºC vertically through a grill on which the bulbs are placed in mesh bags. The treatment is continued for a period of 8 to 12 hrs and provides satisfactory curing for either immediate shipment to markets or storage (Abdelrahman and Ebeaid, 2009).

2.3.4.2 Storage environment

Temperature, relative humidity and gaseous atmosphere can be manipulated to increase the storage life of onion bulbs.The storage regime chosen depends on the cultivar, target storage period and cost (Chope, 2006).

2.3.4.2.1 Storage temperature and relative humidity

The ideal temperature for onion storage is about 0ºCwith60-70% relative humidity (Matosn *et al.,* 1978). Both low temperature (0 - 2.5ºC) and high temperature (25 - 30ºC) have been found to extend dormancy and storage life of onion bulbs (Mahotiere *et al.,* 1976).

In general, sprouting is inhibited both by low and high temperatures and encouraged at intermediate temperatures (Abdalla and Mann, 1963; Brewster, 1977b; Miedema, 1994; Ernst *et al*., 1999). Onion cultivars differ in response of temperature (Gubb and MacTavish, 2002). The optimum temperature range for sprouting is 10-20ºC for most cultivars, with some cultivars displaying a sharp optimum while others have a broader range. Moisture loss was greater at a temperature range of 10ºC - 27ºC.The high temperature inhibition of sprouting may be related to the dormancy observed in hot seasons (Gubb and MacTavish, 2002). Short-term (three weeks), high temperature post-harvest treatments of 30ºC and 35ºC significantly increased the number of days to sprouting in storage at 15ºC, when compared to those exposed to post-harvest temperature treatments of 25ºC (Miedema, 1994a). Short-term (two or three weeks) chilling treatments at 0 or 9°C decreased the time to sprouting in onion bulbs subsequently stored at 18°C. The 9°C treatment for three weeks had the greatest effect, where 100% of bulbs had sprouted after 4-5 weeks. After 8 weeks, only 20% of non-chilled bulbs had sprouted. However, the chilled bulbs had a lower concentration of soluble sugars (Benkeblia and Selselet-Attou, 1999a).

High temperature storage conditions are generally 30-35°C and 60-70% relative humidity. The relative humidity of the storage environment is a compromise between maintaining a level above which pathogens are encouraged and below which water is rapidly lost from the bulbs (Hole *et al*., 2000). The outer scales that protect bulbs against water loss tend to crack and fall off at less than 55% RH, and pathogen attack is encouraged at more than 80% RH. Therefore 60-70% RH is desirable in the storage environment (Chope, 2006).

2.3.4.2.2 Controlled atmosphere storage

Controlled atmosphere (CA) storage involves reduction of O_2 and increase of CO_2 concentrations in the storage environment in addition to cooling (Gubb and MacTavish, 2002). Low O_2 concentration reduces respiration rate and extends storage life, while elevated CO_2 reduces sprouting and root growth (Adamicki, 1998). Low O_2 storage inhibits sprouting, decreases the incidence of neck rot and reduces weight loss. However, very low O_2 concentrations can cause high rates of sprouting after removal from storage, as well as off-odours and tissue break down. Also, high CO_2 concentrations (more than10%) for short-term storage can cause accelerated softening, rotting and off- odours (Chope, 2006). Concentrations of 5% CO_2 and 5% O_2 seem capable of reducing losses from root growth and other disorders (Ryall and Pentzer, 1974).

2.3.5 Traditional storage structures

The storability of onion bulbs is limited by weight loss, sprouting and storage diseases (Abdalla and Mann, 1963). Under poor storage conditions, onion loses water and dry matter and serious losses occur due to rotting, sprouting and rooting (Jones and Mann, 1963). There are many kinds of traditional storage methods, but the most common methods are bulk storage and pallet box storage (Matson *et al.,* 1978). Despite the achievements in production technology, post-harvest losses during storage still pose a great problem (Kukanoor, 2005). Various methods and storage structures have been reported by several workers attempting to reduce these losses. In the Sudan, onion is stored in cottages made up of a wooden frame work covered by a layer of straw. Another type is made up of mud walls and a straw roof with a cylindrical base of approximately 4.5m in diameter, 1.3m high and a conical roof 3m high. Onion bulbs are piled on raised bamboo platforms 40 cm above the ground to allow for ventilation and protection of the stored crop from surface running water during the rainy season (Musa *et al*., 1973).

2.3.5.1 Open field storage in the Gezira State

In the Gezira State, onion is stored in the open field, in jute sacks placed upside down on a cushion of cotton stalks. Onions are exposed to direct sunlight, winds and rains. Consequently, post -harvest losses of 40% or more are not uncommon. Onion perishability and lack of modern storage facilities in the Sudan led to low prices during the harvest season. Hence, it is necessary to store onion in order to ensure an extended supply and increase farmers returns (Musa, 1999).

2.4 Effects of nitrogen on onion yield and storage

Nutrients play a significant role in improving productivity and quality of vegetable crops. Therefore, increasing the productivity of good quality onion is an important target for production. Nitrogen fertilizers are the primary macronutrient taken up in large quantities by plants from the soil relative to other essential nutrients (Marschner, 1995). It comprises 1.5 % to 2.5 % of total dry matter of plants and is a constituent of many fundamental biomolecules (Bungard *et al*., 1999). The beneficial effect of nitrogen application on onion yield was well documented (Tiwori *et al*., 2002, Abdel-Mawgoud *et al*., 2005).

Lee-jongatae *et al.* (1995) found that the highest values for plant height and bulb diameter were obtained at N rates of 180 and 240 kg N/ha, respectively. However, the highest marketable yield was obtained at the rate of 120 kg N/ha. Increasing nitrogen application rates significantly enhanced plant height, number of leaves / plant, fresh weight of plants, bulb weight, marketable and total yields,., However, N application increased percentage of doubles and bolters as well as total soluble solids (Nasrdeen *et al.,* 2007).(Abdissa and pant, 2011) concluded that number of leaves increased by 8% in response to the application of 92kg N/ha, whereas, leaf diameter and bulb length were not influenced by N fertilization rates. Regardless of the rate application, N fertilization increased bulb diameter and average weight of bulb by 12%-21.5%, respectively, over the control. Increasing N application rates generally increased vegetative growth parameters of onion (Rizk, 1997) and significantly increased yield. (Nasrdeen *et al*., 2007).

Excessive Nitrogen has been reported to have adverse effects on storability of onion. The crop grown with high doses of nitrogen tended to mature late in the season and rot and sprout earlier during storage (Kumar *et al*., 2007). Early applications of moderate amounts of N can hasten crop maturity while low N levels can advance maturity (Brewster, 1994). Henriksen (1987) found that late season applications of N or high residual N concentrations in the soil encouraged vegetative growth, delayed or prevented bulbing.

2.5 Effect of sowing date on onion yield and storage

Onion development is dependent on environmental conditions such as photoperiod and temperature (Steer, 1980). During early growth and development, onion requires cool temperatures (6 to 20°C), but during bulb initiation and development, warmer temperatures (25 to 27°C) are required (Comrie, 1997a; Ansari, 2007). Onion cultivars differ with regard to minimum day length required for bulbing and, hence, sowing date is critical and may also differ from year to year (Brewster, 2008).

Although there is no minimum plant size for bulbing, larger plants tend to initiate bulbs earlier even though the required photoperiod is not met (Smittle, 1993). Sowing dates should, therefore, be chosen to ensure that growth takes place under optimum temperatures (16 to 20°C) (Brewster, 2008). Larger plants are more prone to the production of split or double bulbs, which contribute to poor quality (Comrie, 1997). High temperatures (25 -27°C) accelerate bulb initiation causing it to occur at a slightly shorter day length than required for a specific cultivar (Vandenberg *et al*., 1997). However, if bulbing is stimulated when plants are still small, leaf senescence will occur rapidly and small bulbs will be produced due to a small leaf area (Wickramasinghe *et al.,* 2000; Brewster, 2008). Low temperatures (9 to13°C) close to bulb formation will cause plants to bolt instead of forming bulbs even though day length is long enough for bulbing. Early- sown plants will reach bulb formation stage when temperatures are still low and these plants will bolt instead of forming bulbs (Comrie, 1997). This will result in low yields of poor quality onion (Khokhar *et al*., 2007).

Onion production is greatly influenced by sowing date, which is one of the most important factors that greatly influence growth and yield of onion (Mondal and Brewster, 1988). Early planting gives the longest growth cycle (Izquierdo *et al,* 1981). Therefore, emphasis must be given to increase the yield / ha of onion by adopting the optimum sowing date. George *et al.* (2009) and Patil *et al*. (2012) reported that the highest total bulb yield was obtained when onions seedlings were transplanted on early winter.

2.6 Effect of onion cultivars on yield and storage

2.6.1 Effects of onion cultivars on yield

Introduced genotypes such as Baftaim gave highest total marketable yield range of 26.3-44.4 t/ha, compared to the local genotypes such as Abufrewa which a total marketable bulb yield range of (23.9-29.9) t/ha. (Mohammed, 2008)

2.6.2 Storability of the local Sudanese cultivars

The domestic onion cultivars and the Indian cultivars Poona Red had the best keeping quality and storability compared to other cultivars because they were characterized by high dry matter content, high TSS and high pungency (Abu-Gouk *et al*., 2001).

Mohamedali (1978) studied the suitability of several onion introductions and local varieties for the dehydration industry in the Sudan. He reported that the introduced cultivars had a poor keeping quality while the local cultivars, El Hilo, Shendi Yellow and Dongola Early had good storage ability under Hudeiba conditions. The local genotypes (Kamleen, El Hilo, AbuFrewa) showed storage ability better than the introduced genotypes (Baftaim Imporved-1, Baftaim Imporved-2, Baftaim Yellow). This might be due to their well adaptation to the Sudanese conditions, high dry matter and high pungency (Mohammed, 2008).

Onion cultivars differ in their storability. Generally, cultivars with high total soluble solids (TSS) and dry matter contents and high pungency have longer shelf lives compared to mild cultivars with low TSS. Elkashif *et al*. (2006) Reported high significant differences between onion cultivars in weight loss. The least weight loss was recorded for Fadasi, while the highest weight loss was recorded for Baftaim. This can be explained by the fact that Fadasi had higher dry matter and total soluble solids contents compared to Baftaim (Ahmed *et al*., 2015).

Onion storage at 3-5°C and 80%± 5 relative humidity of for 3 to 4 months showed that, onion pungency, moisture content, bulb weight loss and storability depended on onion cultivar (Kopsell and Randle, 1997).Onion storability is directly proportional to pungency and total soluble solids. The red onion cultivars with high levels of dry matter and high pungency were found to be more suitable for long-term storage than the white cultivars with low dry matter content (Bajaj *et al*., 1981).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

This experiment was carried out at Shendi Agricultural Research Station Farm during two consecutive seasons (2014/15 and 2015/16). Shendi is located at 16^{o} 42′N and 33^{o} 62′E and altitude of 366 masl. It lies close to the eastern bank of the river Nile, River Nile State, Sudan. The soil is classified as an Entisols. The parent material of the soil of is river Nile alluvium deposits. It is very deep (more than 2 meters), well drained, leveled and uniform. It has dark grayish brown color on the top (0 – 40 cm) to dark yellowish brown in the sub soil while the structure is clay loam.

3.2 Materials

3.2.1 Cultivars

Materials consisted of two onion cultivars (Baftaim and Abufrewa). Baftiam was obtained from Shandi Agricultural Research Station and Abufrewa was provided by farmers in Shendi area. Baftiam was chosen because it is a popular cultivar which has been recently introduced in the area. Abufrewa is the local cultivar which has been cultivated for a long time and has good storability.

3.2.2 Nitrogen fertilizer

Nitrogen fertilizer was applied in the form urea which was bought from the local market.

Treatments consisted of three sowing dates; 1st December, 1st January and 1st February, two cultivars; Baftaim and Abuferwa and three nitrogen rates; 0, 43 and 86 kg N ha^{-1} the experimental design was a spilt –plot with three replicates. Sowing dates were assigned to the main plots, the cultivars to the sub-plots, and N rates to the sub-sub-plots.

Seeds of the two cultivars were sown in the nursery and transplanted in the field according to the previously mentioned sowing dates. The land was disc plowed, harrowed and made into plots of 3×4m. Onion seedlings were transplanted on flat plots Inter and intra- row spacing was 15 and 10 cm, respectively. Nitrogen in the form of urea was applied in a split dose; two weeks after transplanting and four weeks later. Plot size was 12 m^2.

3.3 Data collected

3.3.1 Vegetative growth

3.3.1.1 Plant height

Plant height (cm) was measured from the ground level to the tip of the longest leaf of five plants randomly selected from the middle rows in each plot, using a meter rule, starting at one month after sowing and monthly intervals.

3.3.1.2 Bulb diameter

Bulb diameter (cm) was measured using a vernier caliper.

3.3.1.3 Bulb Dry matter content

A random sample of sliced fresh onion (five onion bulb) from each treatment was weighed and then placed in the oven at 80°C for 48hrs. The sample was weighed till a constant was obtained. Dry matter content of bulbs (%) was calculated using following equation (Mohamedali, 1978)

$$\text{Dry matter\%} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.3.1.4 Bulb yield

One square meter from the middle rows of each treatment was harvested and total yield in terms of tan per hectare ha was determined.

3.3.1.5 Bulb sorting

The percentages of doubles and bolted bulbs were determined for each treatment.

3.3.1.6 Storability of onion bulbs

Samples of 5 kg of bulbs were taken randomly from each treatment after harvest , packed in jute bags and stored in a well-ventilated store. Bulbs were weighed monthly for a period of 4 months. Cumulative weight loss of onion bulbs was calculated using the following formula:

$$\text{Weight loss (\%)} = \frac{\text{initial weight} - \text{weight at designated time} \times 100}{\text{Initial weight}}$$

3.4 Statistical analysis

Data were subjected to standard analysis of variance procedures. Treatment means were separated using Duncan's Multiple Range Test at 5% level of significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Growth parameters

Tables 1and 2 show highly significant effects of sowing date on the growth parameters of onion. The highest values of growth parameters were recorded for the first of December sowing date and the lowest values were recorded for the first of February in both seasons. This was due to the fact that the first of December sowing date provided low temperatures which encouraged the vegetative growth of onion, however, the late sowing date (first of February) exposed the crop to the early high temperatures of summer which adversely affected vegetative growth. Similar results were obtained by Izquierdo *et al.* (1981) who reported that early planting gave the highest values of growth parameters.

Similarly, Comrie (1997) and Ansari (2007) reported that onion development was dependent on environmental conditions such as photoperiod and temperature. Steer (1980) reported that during early growth and development of onion, cool temperatures of 6 to 20°C were required, but during bulb initiation and development, warmer temperatures of 25 to 27°C were important. The length of the growing period varied with cultivar and climate, but in general, it ranged between 130 to175 days (FAO, 2013).

Table 1. Main effects of sowing date on growth parameters of onion (season 2014/15).

Sowing date	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
1st December	53.0 a	7.6a	21.4 a
1st January	42.0 b	6.5 b	20.5 b
1st February	24.0c	5.3 c	20.2 b
Sig. level	***	***	**
C.V (%)	15.9	14.7	13.1

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

** and *** indicate significance at 1% and 0.1% levels, respectively.

Table 2. Main effects of sowing date on growth parameters of onion (season 2015/16)

Sowing date	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
1st December	49.0a	7.3 a	20.5a
1st January	49.0 a	6.1 b	20.7a
1st February	26.0b	5.3 c	19.8b
Sig. level	***	**	***
C.V (%)	9.4	13.9	13.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

** and *** indicate significance at 1% and 0.1% levels, respectively.

Tables 3 and 4 show significant effects of cultivars on growth parameters of onion in both seasons. The maximum values of plant height and bulb diameter were recorded for Baftaim and the minimum values were recorded for Abufrewa in both seasons. However, the dry matter percentage was highest in Abufrewa and the lowest value was recorded for Baftaim. These results indicated that the introduced cultivar, Baftaim, had more vigorous vegetative growth which resulted in larger bulbs compared to the local cultivar Abufrewa. There was a direct relationship between plant height and bulb size. However, there was a negative relationship between bulb size and dry matter content. Mohammed (2008) reported that the local genotypes had the highest values of dry matter content compared with introduced ones. Mohammedali (2007) reported that the introduced genotypes had high vegetative growth, large bulb size and high yields compared with local genotypes.

Table 3. Main effects of cultivars on growth parameters of onion (season 2014/15).

Cultivars	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
Baftaim	45.5	7.5	15.3
Abufrewa	38.8	6.2	22.8
Sig. level	**	*	**
C.V (%)	15.9	12.6	11.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

*and ** indicate significance at 1% and 5% levels, respectively.

Table 4. Main effects of cultivars on growth parameters of onion (season 2015/16).

Cultivars	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
Baftaim	46.6	7.4	15.4
Abufrewa	40.4	6.3	23.3
Sig. level	*	*	**
C.V (%)	9.4	13.9	14.8

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and ** indicate significance at 5% and 1% levels, respectively.

Tables 5 and 6 show significant effects of nitrogen rate on growth parameters of onion in both seasons. The highest values of plant height and bulb diameter were recorded for the high rate of nitrogen and the lowest values were recorded for the unfertilized control. However, the dry matter content was highest in the unfertilized control and lowest in the highest nitrogen rate in both seasons. This was probably due to the fact that nitrogen application at the higher rate increased bulb size and water content which adversely affected dry matter percentage. Raemaekers (2001) indicated that the high supply of nitrogen by organic and inorganic fertilizers promoted vegetative growth. Rizk (1997) reported that increasing N application rates significantly increased vegetative growth parameters of onion and increased yield but resulted in lower dry matter content.

Table 5. Main effects of nitrogen rate on growth parameters of onion (season 2014/15).

Nitrogen rate (kg N/ha)	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
0	35.5 c	5.6 b	22.6 a
43	41.0 b	7.3 a	20.3 b
86	45.3 a	7.5 a	19.7 c
Sig. level	**	*	**
C.V (%)	15.9	14.4	13.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and ** indicate significance at 1% and 5% levels, respectively.

Table 6. Main effects of nitrogen rate on growth parameters of onion (season 2015/16).

Nitrogen rate (kg N/ha)	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
0	32.2 c	5.2 b	23.1 a
43	38.5b	7.4a	21.3b
86	42.9 a	7.5 a	19.4c
Sig. level	*	*	**
C.V.%	9.4	13.9	14.5

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and ** indicate significance at 5% and 1% levels, respectively.

Tables 7 and 8 show significant interaction effects of sowing date and nitrogen rate on growth parameters of onion in both seasons. The highest values of growth parameters were recorded for the first of December sowing date with the high nitrogen rate and the lowest values were recorded for the first of February sowing date with the unfertilized control in both seasons. This was due to the fact that the first of December sowing date provided low temperatures, which encouraged the vegetative growth of onion, however, the late sowing date (first of February) exposed the crop to the early high temperatures of summer which negatively affected vegetative growth. Jones and Mann (1963) reported that early transplanted onions were subjected to cooler temperatures which resulted in vigorously growing and healthy plants with a large leaf area. Nevertheless, late transplanted onion plants were subjected to shorter cool periods which were not sufficient for the enhancement of vegetative growth.

The high nitrogen rate promoted vegetative growth by increasing photosynthetic efficiency, nutrient and water uptake. Rizk (1997) reported that increasing N application rates generally increased vegetative growth parameters.

However, the highest values of dry matter content were recorded for the unfertilized control in all sowing dates and the lowest values were recorded for the highest nitrogen rate in all sowing dates in both seasons. These results indicated a negative correlation between dry matter content and applied nitrogen in all sowing dates. This was most probably because the high nitrogen rate resulted in large bulb sizes with high water content which negatively affected dry matter content compared with the unfertilized control.

Table 7. Interaction effects of sowing date and nitrogen rate on growth parameters of onion (season 2014/15).

Sowing date	Nitrogen rate (kg N/ha)	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
1st December	0	44.4 c	5.6e	22.6a
	43	53.6 b	7.3b	20.3b
	86	61.7 a	7.5a	19.5b
1st January	0	38.1 d	5.5f	22.5a
	43	42.2 c d	7.2cd	20.1b
	86	47.9 c	7.4b	19.2b
1st February	0	23.1e	5.1g	22.1a
	43	24.0 e	7.2cd	19.9b
	86	26.1 e	7.3c	19.1bc
Sig. level		**	*	**
C.V (%)		15.9	11.0	12.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and ** indicate significance at 5% and 1% levels, respectively.

Table 8. Interaction effects of sowing date and nitrogen rate on growth parameters (season 2015/16).

Sowing date	Nitrogen rate (kg N/ha)	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
1st December	0	35c	6.0b	22.4a
	43	42b	7.4a	20.6b
	86	51 a	7.6a	19.6c
1st January	0	29.7 d	5.6b	22.3a
	43	37 c	7.2a	20.5b
	86	45 b	7.3a	19.3c
1st February	0	24d	5.2bc	22.9a
	43	26d	7.1a	20.0b
	86	28 d	7.2	19.0c
Sig. level		**	*	*
C.V (%)		9.4	8.9	9.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
* and ** indicate significance at 5% and 1% levels, respectively.

Table 9 shows significant interaction effects of sowing date and cultivars on growth parameters of onion in the first season only. The highest values of plant height and bulb diameter were recorded for the first of December sowing date with Baftiam and the lowest values were recorded for the first of February sowing date with Abufrewa. This may be due to the fact that the first of December sowing date provided low temperatures which encouraged the vegetative growth of onion. However, the late sowing date (first of February) exposed the crop to the early high temperatures of summer which negatively affected vegetative growth. The highest values of dry matter content were recorded for the first of February sowing date with Abuferwa and the lowest values were recorded for the first of December sowing date with Baftaim cultivar. There was a negative correlation between bulb size and dry matter content. The early transplanting of the introduced Baftaim cultivar gave large bulb sizes, high water content and low dry matter content of bulbs compared with late transplanting. Mohammed (2008) reported that the local genotypes gave the highest values of dry matter content compared with introduced genotypes.

Table 9. Interaction effects of sowing date and cultivars on growth parameters of onion (season 2014/15)

Sowing date	Cultivars	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
1st December	Baftaim	58.2a	7.4a	17.4c
	Abufrewa	47.8b	6.3b	22.4b
1st January	Baftaim	47.9b	7.2a	18.2c
	Abufrewa	40.1c	6.9 b	23.4a
1st February	Baftaim	28.4d	5.8b	18.6c
	Abufrewa	23.4e	5.1bc	23.9a
Sig. level		*	*	**
C.V (%)		15.9	31.0	21.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
* and ** indicate significance at 5% and 1% levels, respectively.

The interaction effects of sowing date, cultivars and nitrogen rate on bulb dry matter content were significant in the first season only (Table 10). The highest dry matter content of bulbs were recorded for Abufrewa cultivar which received no N and transplanted on the first of January or the first of February and the lowest were recorded for Baftaim cultivar which received 86 kg N/ha and transplanted on the first of December. These results indicated that dry matter content was increased with delayed sowing date and without fertilization. Also, there was a negative correlation between the large bulb size of Baftaim and dry matter content. Mohammedali (2007) reported that Abufrewa cultivar proved to have exceptionally high dry matter content compared to Baftaim.

Table 10. Interaction effects of sowing date, cultivars and nitrogen rate on bulb dry matter content % (season 2014/15)

Sowing date	Cultivars	Nitrogen rate (kg N/ha)		
		0	**43**	**86**
1st December	Baftaim	17.4c	16.2d	15e
	Abufrewa	22.3b	21.9b	20.3bc
1st January	Baftiam	18.2c	17.1cd	16.3d
	Abufrewa	23.4a	22.4b	21.1bc
1st February	Baftaim	18.5c	17.7c	17.0d
	Abufrewa	23.9a	22.3b	21.4c
Sig. level	***			
C.V (%)	11.72			

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
*** indicate significance at 0.1% level.

4.2 Bulb quality and total yield

Tables 11and 12 show significant effects of sowing date on bulb quality and total yield of onion in both seasons. The highest values of bolters, doubles and total yield were recorded for the first of December sowing date and the lowest values were recorded for the first of February sowing date in both seasons. Early transplanting subjected onion plants to cooler temperatures which resulted in vigorous and healthy growing plants with a large leaf area which promoted the production of large bulbs and, hence, increased total yield. Along the same lines, the low yield obtained in the late sowing date was probably due to the fact that late transplanting subjected onion plants to a shorter cool period and warm temperatures which were not sufficient to enhance vegetative growth and, hence, resulted in low yields. Also, late transplanting resulted in small-sized bulbs with reduced incidence of doubles and bolters. Similar results were reported by Nourai (1994) who showed that high onion yields were recorded by early transplanting and were associated with an increased bulb size and increased incidence of doubles and bolters.

Table 11. Main effects of sowing date on bulb quality and total yield of onion (season 2014/15).

Sowing date	Bolters (%)	Doubles (%)	Total yield (t/ha)
1st December	64.2a	30.8a	45.5 a
1st January	53.7b	25.4b	32 b
1st February	32.9c	23.6b	27 c
Sig. level	***	***	***
C.V (%)	15.4	12.2	29.0

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

*** indicate significance at 0.1% level.

Table 12. Main effects of sowing date on bulb quality and total yield of onion (season 2015/16)

Sowing date	Bolters (%)	Doubles (%)	Total yield (t/ha)
1st December	61.2a	32.8a	41.0a
1st, January	50.1b	27.2b	28.0b
1st February	37.6c	24.1c	23.0c
Sig. level	*	**	**
C.V (%)	18.3	15.7	21.6

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and** indicate significance at 5% and 1% levels, respectively.

Tables 13 and 14 show significant effects of cultivars on bulb quality and total yield in both seasons. Baftaim cultivar had the lowest values of doubles and bolters but had the highest total yield, whereas Abufrewa cultivar recorded the highest values of doubles and bolters and the lowest total yield in both seasons. These results indicated that the introduced cultivar Baftaim was superior to the local cultivar Abufrewa in both bulb quality and total yield. These results were in agreement with those of Mofadel *et al.* (2000) who reported that the introduced cultivar such as Baftaim showed higher values of bulb weight compared to the local cultivar such as Abufrewa. Hassan (1984) reported that the doubles phenomena was related to genetic factors and affected by specific cultural practices such as sowing date and plant density.

Table 13. Main effects of cultivars on bulb quality and total yield of onion (season 2014/15).

Cultivars	Bolters (%)	Doubles (%)	Total yield (t/ha)
Baftiam	28.6b	20.0b	45.0 a
Abufrewa	45.0a	29.5a	28.4 b
Sig. level	*	*	**
C.V (%)	15.4	12.2	21.0

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and** indicate significance at 5% and 1% levels, respectively.

Table 14. Main effects of cultivars on bulb quality and total yield of onion (season 2015/16).

Cultivars	Bolters (%)	Doubles (%)	Total yield (t/ha)
Baftaim	35b	19b	42a
Abufrewa	46a	32a	23b
Sig. level	*	**	**
C.V (%)	18.3	15.7	21.6

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and** indicate significance at 5% and 1% levels, respectively.

Tables 15 and 16 show significant effects of nitrogen rate on bulb quality and total yield of onion in both seasons. The highest values of doubles, bolters and total yield were recorded for the highest nitrogen rate and the lowest values were recorded for the unfertilized control in both seasons. This was most probably due to the fact that N encouraged vegetative growth which resulted in large bulbs and high yields. However, large-sized bulbs were always associated with premature bolting and splitting. These findings were in accordance with those reported by Nourai (1992) who found that the application of nitrogen at the rate of 86 kg N/ha significantly increased total onion yield but also increased the percentages of doubles and bolters.

Table 15. Main effects of nitrogen rate on bulb quality and total yield of onion (season 2014/15).

Nitrogen rate (kg N/ha)	Bolters (%)	Doubles (%)	Total yield (t/ha)
0	48.0c	23.5c	33.2c
43	53.0b	26.4b	41.5b
86	64.0 a	33.0a	46.1a
Sig. level	*	**	**
C.V (%)	15.4	12 .2	29.0

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and ** indicate significance at 5% and 1% levels, respectively.

Table 16. Main effects of nitrogen rate on bulb quality and total yield of onion (season 2015 /16).

Nitrogen rate (kg N/ha)	Bolters (%)	Doubles (%)	Total yield (t/ha)
0	42c	21.5c	30.0c
43	50b	29.0b	39.3b
86	61a	35.0a	44.7a
Sign.	*	*	**
C.V.%	16.3	19	22.8

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and** indicate significance at 5% and 1% levels, respectively.

Table 17 shows significant interaction effects of sowing date and cultivars on bulb quality and total yield in the first season only. The highest values of total yield were recorded for Baftaim cultivar transplanted in the first of December and the lowest values were recorded for Abufrewa transplanted in the first of February. Abufrewa cultivar had higher percentages of bolters and doubles compared with Baftaim.

Similar results were obtained by Nourai (1992) who reported that high onion yields were produced from early transplanting, but with high percentages of doubles and bolters. These results were also in agreement with the findings of Mohammed (2008) who reported that the percentage of doubles varied greatly among cultivars and the lowest percentage was obtained from the introduced Baftaim cultivar compared to the local cultivar Abufrewa.

Table 17. Interaction effects of sowing date and cultivar on bulb quality and total yield of onion (season 2014/15).

Sowing date	Cultivars	Bolters (%)	Doubles (%)	Total yield (t/ha)
1st December	Baftaim	21.6d	19.7d	45.2a
	Abufrewa	39.4 a	24.1c	30.9c
1st January	Baftaim	18.8e	26.1c	37.7b
	Abufrewa	33.9b	31.5b	26.7d
1st February	Baftaim	17.3e	31.7b	31.9c
	Abufrewa	26.4c	37.0a	21.6e
Sig. level		*	*	**
C.V (%)		15.4	12.2	12.0

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
* and ** indicate significance at 5% and 1% levels, respectively.

4.3 Weight loss

Table 18 shows significant effects of sowing date on weight loss of onion during storage in the second season only. The highest values of weight loss were recorded in the first of December sowing date and the lowest values were recorded in the first of February sowing date. This was probably due to the fact that early transplanting resulted in large bulbs with low dry matter content which subjected them to high water loss compared with small bulbs with high dry matter content in the late transplanted onion. These results are in line with those of Nourai (1992) who reported that the percentage of weight loss during storage was higher in the early transplanted onion.

Table 18. Main effects of sowing date on cumulative weight loss (%) of onion during storage (season 2015/16).

Sowing date	months			
	Cumulative weight loss (%)			
	1	**2**	**3**	**4**
1st December	23.4a	26.9a	34.5a	43.6a
1stJanuary	17.7b	23.6b	29.1b	38.3b
1st February	13.3c	18.5c	25.2c	32.7c
Sig. level	***	**	**	*
C.V (%)	11.8	8.8	8.9	6.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
*, ** and *** indicate significance at 5%, 1% and 0.1% levels, respectively.

Tables 19 and 20 show significant effects of cultivars on weight loss of onions during storage in both seasons. Abufrewa recorded the least percentage of weight loss compared to Baftaim which recorded the highest percentage of weight loss in both seasons. This was most probably due to the fact that the local cultivar Abufrewa had high dry matter content and high pungency which resulted in lower weight loss. These results are in line with the reports of Ryall and Lipton (1983) who mentioned that the characteristics which enhanced superior storage quality of onion were high total soluble solids, high dry matter content and pungency. Mohmedali (1977) reported that the introduced genotypes had a poor keeping quality while the local genotypes had good storage ability.

Table 19. Main effects of cultivar on weight loss (%) of onion during storage (season 2014/15).

Cultivars	**months**			
	Cumulative weight loss (%)			
	1	**2**	**3**	**4**
Baftaim	17.3	22.5	29.9	46.1
Abufrewa	10.6	16.3	17.8	27.7
Sig. level	*	*	*	*
C.V (%)	13.9	11.8	10.2	7.2

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
* indicate significance at 5% level.

Table 20. Main effects of cultivar on weight loss (%) of onion during storage (season 2015/16).

Cultivars	**months**			
	Cumulative weight loss (%)			
	1	**2**	**3**	**4**
Baftaim	25.3	38.0	50.6	57.5
Abufrewa	11.6	14.7	18.9	27.3
Sig. level	*	*	*	*
C.V (%)	11.8	11.6	8.9	6.8

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
* indicate significance at 5% level.

Tables 21 and 22 show significant effects of nitrogen rate on weight loss of onion during storage in both seasons. Generally, weight loss increased with increasing nitrogen rate. The highest values of weight loss were recorded for the highest nitrogen rate (86 kg N/ha) and the lowest values were recorded for the unfertilized control in both seasons. This was most probably due to the fact that the high nitrogen rate resulted in large bulbs with low dry matter and high water content which made them more vulnerable to increased water loss. These results are in agreement with those reported by Hurst (1985) who stated that cultivars of low dry matter content and less pungency were grown for the fresh market for consumption and generally did not store very well. Similar results were reported by many research workers who found that high levels of nitrogenous fertilizer resulted in reduced onion storage life (Kato *et al*., 1987; Singh and Dhankar, 1991; Batal *et al*., 1994).

Table 21. Main effects of nitrogen rate on weight loss (%) of onion during storage (season 2014/15).

Nitrogen rate (kg N/ha)	months			
	Cumulative weight loss (%)			
	1	2	3	4
0	12.0c	18.0c	24.4c	31.1c
43	15.7b	21.4b	28.5b	35.5b
86	21.4a	27.3a	33.7a	39.9a
Sig. level	***	***	***	***
C.V (%)	13.9	11.8	10.2	7.2

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

*** indicate significance at 0.1% level.

Table 22. Main effects of nitrogen rate on weight loss (%) of onion during storage (season 2014/16).

Nitrogen rate (kg N/ha)	months			
	Cumulative weight loss (%)			
	1	2	3	4
0	14.2c	21.1c	27.2b	33.7c
43	17.3b	23.2b	29.7b	36.9b
86	22.8a	28.4a	34.2a	38.7a
Sig. level	***	**	**	**
C.V (%)	11.8	11.6	8.1	6.7

Means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

** and *** indicate significance at 1% and 0.1% levels, respectively.

CHAPTAR FIVE
CONCLUSIONS AND RECOMMENDTION

5.1 Conclusions

- The first of December sowing date resulted in the best vegetative growth and highest yield. However, it resulted in the least dry matter content and highest weight loss compared to the late sowing date in both seasons.
- Baftaim cultivar had more vigorous vegetative growth and higher yield compared to Abufrewa. However, Abufrewa had higher dry matter content and lower weight loss compared to Baftaim in both seasons.
- Application of N at 86 kg / ha resulted in the best vegetative growth and highest yields for both cultivars and in all sowing dates. However, the high N rate resulted in lower dry matter content and higher weight loss compared to the unfertilized control in both seasons.

5.2 Recommendations

It is recommended to transplant Baftaim cultivar in the first of December for in mediate marketing and grow Abufrewa in the first of February for long term storage.

It is also recommended to apply N at the rate of 86 kg / ha for the best vegetative growth and highest yields.

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