EFFECT OF PLANTING TIME ON GROWTH, YIELD COMPONENTS, SEED YIELD AND QUALITY OF ONION (*Allium cepa* L.) AT TEHULEDERE DISTRICT, NORTH EASTERN ETHIOPIA.

MSc THESIS

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Jimma, Ethiopia
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By

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A Thesis

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DEDICATION

I dedicate this thesis to my family for nursing me with affection and love and their unwavering support for success in my life.

STATEMENT OF THE AUTHOR

I, the undersigned, declare that this thesis is my original work and is not submitted to any institution elsewhere for the award of any academic degree, diploma or certificate and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc degree at the Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the library.

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Place: Jimma University

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BIOGRAPHICAL SKETCH

Maria Tesfaye Gebeyehu, the author, was born in Haik town on March 18, 1991. She attended her elementary, secondary and preparatory school at Sulula, Catholic and Memhr Akalewold Dessie School, respectively. She joined Mekelle University in 2010 and graduated with B.Sc degree in Dry Land Crop Science in July 2012.

After her graduation, she was employed by the Ministry of Agriculture at Tehuledere woreda and served for two years. In October 2014, she joined Jimma University to pursue her M.Sc. degree in Agronomy through financial grant obtained from ILRI (International Livestock Research Institute).

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CRV	Central Rift Valley
CSA	Central Statistical Agency
DAP	Di ammonium Phosphate
DMC	Dry Matter Content
DNA	Deoxyribo Nucleic Acid
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization of The United Nations
GDD	Growing Degree Day
DL	High Density Lipoprotein
ILRI	International Livestock Research Institute
JARSC	Jari Agricultural Research Sub Center
LSD	Least Significant Difference
m.a.s.l	meter above sea level
MoARD	Ministry of Agriculture and Rural Development
MT	Metric Tone
RCBD	Randomized Complete Block Design
RGR	Relative Growth Rate
RLGR	Relative Leaf Growth Rate
RH	Relative Humidity
SAS	Statistical Analysis System
TSS	Total Soluble Solids

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EFFECT OF PLANTING TIME ON GROWTH, YIELD COMPONENTS, SEED YIELD AND QUALITY OF ONION (*Allium cepa*L.) AT TEHULEDERE DISTRICT, NORTH EASTERN ETHIOPIA

ABSTRACT

Onion (Allium cepa L.*) is member of the family Alliaceae and the most widely grown herbaceous biennial vegetable crop. Quality planting material is one of the major inputs to successful vegetable production. However, it is one of the major constraints in Ethiopia. Northeastern Ethiopia has suitable agro-climatic condition for onion seed production. However, onion seed production packages, including its appropriate planting time, are not yet determined. Evidences on effects of the different planting time on quality and yield level is not well explored. Therefore, this experiment was conducted at Jari small scale irrigation scheme from September 2015 to April 2016 to determine an appropriate planting time for a better plant growth, yield components, seed yield and quality of Adama red onion variety. The experiment was laid out in randomized complete block design with three replications. Treatments were nine planting dates: 1st September, 16th September, 1st October, 16th October, 31st October, 15th November, 30th November, 15th December and 30th December. Data were collected on growth, yield components, seed yield and quality parameters and analyzed using SAS version 9.2 statistical software. Analysis of variance revealed that plant height, number of leaves per plant, number of scapes per plant, scape diameter, scape height, days to 50% flowering and maturity, umbel diameter, number of seeds per umbel, 1000-seed weight, seed yield and germination percentage were significantly influenced by planting time. The highest seed yield (1032.7kg/ha) as well as the highest germination percentage (94.3%) were recorded from onion planted early (1st September). On the other hand, the lowest seed yield (29.7kg/ha) and germination percentage (15.3%) recorded from onion planted late (December). Growth, yield components, seed yield and quality parameters were negatively and significantly correlated with planting time. Therefore, 1st September is recommended as appropriate planting time for onion seed production at Jari, Northeastern Ethiopia. Since this result is based on one season work, in order to give conclusive recommendation, further investigation is needed at Tehuledere district and other locations with similar agro-ecological conditions in the region.*

1. INTRODUCTION

Onion (*Allium cepa* L.) is member of the family Alliaceae and the most widely grown herbaceous biennial vegetable crop with cross pollinated and monocotyledonous behavior having diploid chromosome number (2n = 16) (Hanelt, 1990). Onion is different from the other edible species of *Allium* for its single bulb and is usually propagated by true botanical seed. It is believed to have originated in Afghanistan, the area of Tajikistan and Uzbekistan, western Tien Shan and India while western Asia and the areas around the Mediterranean Sea are secondary centers of diversity (Saud *et al*., 2013).

It has been cultivated for more than 5000 years and does not exist as a wild species (Schwarth and Mohan, 1999). Onions are used primarily as flavoring agents and their distinctive pungency and form essential ingredients for flavoring varieties of dishes, sauces, soup, sandwiches, snacks as onion rings etc. And which increase the taste of food (Rahim, 1992); freshly cut onions often cause a stinging sensation in the eyes of people nearby, due to the presence of a volatile oil (allyl propyl disulphide). The mature bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B, and C (Elhag and Osman, 2013;Opara, 2003). It is also one of the richest sources of flavonoid in the human diet and flavonoid consumption has been associated with a reduced risk of cancer, heart disease and diabetes. In addition it is known for anti-bacterial, antiviral, anti-allergenic and anti-inflammatory potential and used as preservative and medicinal plant (MoARD, 2009).

The world production of onion is about 3944 million MT per years from 3.17 million ha (FAO, 2011); more than 90% of which is consumed within the countries of production. About 9,745.36 tons of onion seed was produced in the world with maximum seed yield (17.269 t/ha) was obtained in the world (FAO, 1999). With respect to its importance; onion stands second, following tomato and with respect to production, it ranks fourth in the world (Abdolhossein and Sayed, 2015). Onion is grown in more than 175 countries in the world. Based on the average production from 2008-2013, the world's top producer of onion is China, contributing an average of 31% to the total production followed by India (10%) (FAOSTAT, 2011).

In Ethiopia it ranks first among *Allium* species both in area coverage and total production (CSA, 2014). Its area coverage was 24,357.7 ha and total annual production was 219,735.3 tons, but in the year of 2014/2015 the production has increased to 230,745.2 tons and the average productivity of onion was increased from 9 to 10.1 t/ha (CSA, 2014, 2015) and its seed yield per hectare was 1.3 tons Lemma and Shimels (2003). As compared to the world average, Ethiopia's onion seed yield per hectare is very low; this may be due to effect of genotype, locality, season, soil type, and method of seed production (Brewster, 1994).

The area coverage of onion is steadily increasing mainly due to its high profitability, ease of production, and the expansion of irrigation infrastructure in different parts of the country (Olani and Fikre, 2010; Weldemariam Seifu *et al*., 2015). Likewise the demand for quality onion seed is increasing (Amsalu *et al*., 2014). However, seed supply is inadequate, its price is increasing every year and onion seed available in the market are poor in quality (Olani and Fikre, 2010). Onion seeds are poor in keeping quality and lose viability within a year. Owing to these challenges, onion seed production gradually started by smallholder farmers in different parts of the country.

Onion seed production is influenced by many factors, among which varieties, bulb size, soil, climate, spacing, fertilizer application, planting time are important. Cool weather with ample moisture supply is required for flower stalk initiation. Then drier conditions with good sunshine are required for pollination, seed maturity, harvesting and processing (Olani and Fikre, 2010). High temperature during flowering result in flower abortion, subsequently result in lower seed yield. On the other hand, very low temperature, foggy weather and rainfall during flowering time affect the movement of honey-bees and pollination process. Rainfall during harvesting time adversely affects the quality of onion seed. Therefore, selection of appropriate planting time in a given locality is crucial for onion seed production.

The effect of planting time on onion seed production was studied by several researchers in different parts of the world and reported its significant effects both on productivity and quality. Ud-Deen (2008) studied the effect of different planting dates and recommended 30th October as the best planting date for onion seed production in Bangladesh. On the other hand, Mollah *et al.* (2015) assessed the effect of different planting dates on onion seed production in

Borga, Bangladesh and identified 15th November as the best planting date for onion seed production. El-Helaly and Karam (2012) identified mid of November as the best planting date for onion seed production in Giza region of Egypt. Mehri *et al.* (2015) in Iran assessed two onion varieties and reported appropriate planting time for seed production to be from 22nd September to 6th October.

Although Ethiopia has very diverse agro ecology, the number of studies on the effect of planting time on onion seed production is very limited. Studies in central Ethiopia showed that onion seed production is best if mother bulbs are planted in September and October for flowering to take place in the months of January and February in cooler and drier months (Olani and Fikre, 2010). Teshome *et al.* (2014) recommended October 25th as the best planting date for onion seed production in Kobo, North Wollo. The above findings depict the importance of identifying appropriate planting time for onion seed production in each locality and for each variety. Therefore, the present study was conducted to identify the appropriate planting time for onion seed production and associated selected seed quality indicators in Tehuledere district, Northeastern Ethiopia.

1.1 Statement of the problem

Planting time is one of the most important factors for onion seed production as it is associated with temperature. Limitation of cool weather conditions to induce flowering is the main constraint of onion seed production in many tropical countries, including Ethiopia. As a result, many countries have to import onion seed from sub-tropical or temperate countries where the winter season provides the chilling requirement for flowering. The demand for quality, true-to-type seeds is increasing from time to time. The price of quality seeds is also high. Environmental conditions greatly influence growth and development of onion plant, and growth phases of onion have different environmental requirements (Ziant *et al*., 2012)

Onion bulbs require a certain period of cool treatment (vernalization time) for maximum flowering of the stalks. Cool temperature for bulb was important to ensure effective flowering of seed crop. In addition of this, the seeds available in the market are poor in quality (Lemma and Shimeles, 2003). Most of the time germination is poor and the problem is further exacerbated by its short shelf life (one year under favorable condition). Owing to these, producers are commonly using 6- 8 kg of seeds per hectare as opposed to the recommended rates of 3.5-4 kg/ha in order to guarantee good seedling emergence (Lemma and Shimeles, 2003; Teshome *et al.*, 2014). This incurs more cost to farmers besides the ever increasing price of onion seed on the local markets. All these are hampering the advancement of onion production.

Study on planting time and cultivar selection to improve quality of seed is limited. This is one of the problems of farmers around the current research site as well as many parts of Ethiopia. In North Wollo, onion is one of the widely grown vegetable crops and the area has also suitable climate for onion seed production. Onion seed yield per hectare at Kobo (North Wollo) is 1.156 t/ha (Teshome *et al*., 2014). Similarly, Tehuledere district has suitable climate for onion bulb and seed production. However, there is no experience on onion seed production in the district and farmers are dependent on seed produced in other parts of the country or imported from abroad. Keeping all these above facts in view, the present study was therefore, undertaken to determine an appropriate planting time for better plant growth, yield components, yield and quality of onion seed.

1.2 Objective

To determine the appropriate planting time for a better plant growth, yield components, yield and quality of onion seed at Tehuledere district.

2. LITERATURE REVIEW

Onion is an herbaceous, biennial and monocot crop. It takes two seasons for seed production, and during the first season bulbs are formed while flower stalks and seeds are developed in the second season **(**Brewster, 2008). Onion is grown mainly for its bulb, although the green shoots are important to prepare salad. Onion requires deep alluvial and friable or sandy loam soil with a pH of 6.0-6.8 (Brewster, 1994).

2.1. The Onion Crop

The onion bulb consists of the swollen bases (sheaths) of bladed leaves surrounding swollen bladeless leaves. Each leaf consists of a blade and sheath; the blade may or may not be distinctive. The sheath develops to encircle the growing point and forms a tube that encloses younger leaves and the shoot apex. Collectively, the grouping of these sheaths comprises the pseudo stem. Leaves arise from the short, compressed, disc like stem which continues to increase in diameter with maturation and resembles an inverted cone (Bosekeng, 2012). The onion skin is formed from the dry paper like outermost leaf scales that lose their freshness during bulbing. Major bulb quality features are uniformity of shape, size and skin colour, pungency and dry matter (Rubatzky and Yamaguchi, 1997).

The test and odor characteristics of the alliums are their major attribute. Other features are the umbel inflorescence, flower with nectars, a three-chambered ovary and a basic chromosome number of eight for the cultivated species. The major flavor of alliums results from the activity of the enzymes, alliinase, acting on certain sulfur-containing compounds (S. alkyl cysteine sulfoxides) when tissues are broken or crushed. Onion roots are shallow, most occur within 15-20 cm of the surface, and seldom extends horizontally beyond 50 cm. Onion roots are short lived, being continuously produced. Roots rarely have branch and rarely increase in diameter (Brewster, 1994). The terminal inflorescences develop from the ring like apical meristem scapes and generally elongate well above the leaves and ranges in height from 30 to more than 100 cm. The scape is the stem internodes between the spathe and the last foliage leaf. At first, the scape is solid but, by differential growth, becomes thin walled and hollow.

The number of scapes that develop depends on the number of sprouted lateral buds. A spherical umbel is borne in each scape and can range from 2 to 15 cm in diameter.

The umbel is an aggregate of many flowers at various stages of development; usually there are 200-600 small individual flowers. The flowering periods may last four or more weeks. Flowers are perfect, having six white petals, six stamens and a three carpel pistil. Flowers have nectars, an attractant to pollinating insects, usually honey bees.Alliums have perfect flowers but, cannot self-pollinate because the male anthers shed pollen before the female stigma is receptive. Therefore, they cross-pollinate via insects (flies and bees) or by manually pollinating (hand-pollinating) the flowers in a controlled environment. Seed producers must keep in mind that varieties of the same species will cross-pollinate with other varieties of the same species (Currah and Proctor, 1990).

After pollination, fertilization of ovules starts within 12 h and is complete in 3–4 days. Pollination itself stimulates the initial development of ovules and ovaries. In fertilized ovules, the endosperm nuclei start to divide and cell division and expansion by the embryo occurs 5–6 days later. The embryo reaches its full development when the seed attains maximum dry weight. Initially the endosperm is liquid, and this is termed as the ‘milk stage’ (Jilani, 2004).

But at about seventeen days after pollination, cell walls develop within the endosperm and it progresses to the pasty ‘dough stage’. At this point, the seed coat starts to turn black. Later on seed attains its maximum fresh weight at about 30 days after flowering. Up to this point, seed dry weight growth is near exponential and seed dry weight is then about half its maximum. The endosperm then becomes solid and the seed reaches its maximum dry weight. After flowering, life completed and on maximum maturity day, the flower turns to give seed. The seeds may be up to 300 per gram (Currah and Proctor, 1990).

Onion seed matures about 45 days after anthesis. Seed are black, irregular shaped, and relatively small and about 200 seeds weigh one gram. Seeds lose viability rapidly unless stored under optimal condition of 0^oC and low RH. Under high temperature and humidity of tropical conditions, its viability may be less than a year in the tropics; the growers use short-day variety because day length is shorter in the tropics than that of temperate zones (Anonymous,Allium,Webaddress,http://cms.cnr.edu.bt/cms/files/docs/Five/vegetables%20production/Study%20guides/).

2.2. Onion Varieties in Ethiopia

Different types of onion cultivars are available in Ethiopia. These are fresh market, bunching and dehydrator types, which could be open pollinated, or hybrids. The fresh market types (red colored, highly pungent) have high acceptance in the local market compared to bunching and dehydrator types. The dehydrator onions are large and are commonly produced for flaxes, onion powder, and onion rings that are mainly used for snacks. The onion cultivars vary in vegetative characteristics such as foliage length, leaf arrangement (erect, pending) and leaf color. They also differ in bulb characteristics, internal structure (single, double, multiple) bulb shape (flat to cylindrical to spindle), color (red, yellow, white), flavor rate (sweet, mid pungent and pungent) (Geremew *et al*., 2010).

The five common varieties of onion in Ethiopia are Adama Red, Bombey Red, Red Creole, Melkam, and Nasik Red (Dereselegn). Bombay Red and Adama Red varieties are widely grown in Ethiopia (EARO, 2004). Oromia National Regional State is the most important production region for onions (64%), followed by Amhara National Regional State (30%) (CSA, 2008/09). Adama Red is a dark red colored and firm, very pungent, flat globe shaped. It flowers and set seed very easily. It is accepted both by producers and consumers and is successfully produced by small farmers and commercial growers in most regions of the country. The cultivars are grown in Awash valley and Lake Region in larger quantity. Melkam, high yielder but light red in bulb color than Adama Red (Kahsay *et al.*, 2013).

Red Creole is red colored and firm, very pungent, not easily bolting, relatively tolerant to purple blotch disease. Bombay Red is thick, flat shaped, light red, light pungent, susceptible to purple blotch disease. It has a high proportion of split bulbs and has short shelf life compared to Adama Red. Dereselgn (Nasik Red) is early maturing; medium red, large bulb sizes and fits to short growing season. Adama Red and 'Nasik' Red having DMC (%) of 17.67 and 17.27, respectively showed higher and significant difference from 'Melkam' and

‘Bombay’ Red which had DMC (%) of 15.23 and 14.41, respectively. Adama Red variety was found to be superior for quality in terms of TSS content, DMC and storability (Kahsay *et al.*, 2013).

Table1. Characteristics of different onion varieties

Onion Cultivar	Maturity Days	Bulb Color	Bulb Shape	Bulb Size(g)	Bulb Yield (qt/ha)	Seed Yield (qt/ha)
Adama Red	120-135	Dark Red	Flat Globe	65-80	350	10-13
Red Creole	130-140	Light Red	Flat Globe	60-70	300	2-6
Bombay Red	90-110	Red	Flat Globe	70-80	300-400	13-20
Melkam	130-142	Red	High Globe	85-100	400	11-15
Dereselegn	100-115	Red	Globe	85-100	380	-

Source: Lemma and Shimels (2003)

2.3. Climatic Requirement

2.3.1. Temperature

Most of the onion varieties are adapted to low and mid altitude areas (700-1800 m.a.s.l), even though onion can grow up to 2000 m.a.s.l. The ideal temperature for mother bulb production is 18^0C to 24^0C day and 10^0C to 12^0C night temperature. For bulb production it can go higher beyond these ranges. However, it is major factor for flower stalk development and seed set. Higher temperature can prevent flowering. After bulb develops, cool weather with ample moisture supply is required for flower stalk initiation (Olani and Fikre, 2010).

Temperature controls the development and the performance of the onion plant in all its growth phases (Coolong and Randle, 2003). To obtain germination percentage of at least 70% and temperature between 7.5°C and 30°C is needed (Abu-Rayyan *et al.*, 2012). According to Shanmugasundaram and Kalb (2001), onion seedlings grow best at temperatures between 20°C and 25°C.

2.3.2. Photoperiod

Onions react to day length for bulb initiation and the leaves of the plant are the photoperiodic stimulus receptor (Okporie and Ekpe, 2008). As the photoperiodic stimulus is received, formation of bladed green leaves near the apical meristem ceases and only bladeless leaves are formed. The photoperiodic stimulus favors carbohydrate accumulation exported from the leaf blade to the leaf sheath (Mondal *et al*., 1986), causing the sheaths of the leaves to thicken and enlarge. These thickened leaf sheaths will develop into a storage organ, the bulb. As the bulb matures, the outer (oldest) one to four leaf scales dry out and become protective skin (Brewster, 1994).

The day length requirement for bulb formation differs according to cultivar type, ranging between 12 and 16 hours (van den Berg *et al*., 1997). Adaptation of onion cultivars to a certain production area is largely dependent on the day length of that area and the day length requirement of the specific cultivar (Wiles, 1989). Short day onion cultivars require a day length of 11-12 hours for bulb formation, and can be planted in the tropics (30°N and S from the equator) (Wiles, 1989). The day length in this area remains close to 12 hours throughout the year. Intermediate day cultivars require a day length of 12-14 hours for bulbing and can be planted in areas between 30° and 45° latitude as a winter or spring sown crop. Long day onion cultivars requiring a day length of 16 or more hours for bulbing are well adapted to areas between 45° to 60° latitude (Van den Berg *et al*., 1997).

A cultivar sown in areas where the photoperiod is longer than required, premature bulb formation is enhanced, bulb development and maturity rates increase, and this will result in smaller bulbs and low yields (Wickramasinghe *et al*., 2000). Photoperiod of a specific production area at the time of bulb initiation will therefore influence cultivar selection. In the tropics, the growers use short-day variety because day length is shorter in the tropics than that of temperate zones (http://cms.cnr.edu.bt/cms/files/docs/ Five/vegetables%20production/Study%20guides/). In Bangladesh, short-day length prevails in the growing seasons (winter) of onion (Ud-Deen, 2008), so to minimize the cultivation and production problems, emphasis must be given to improve cultivation methods of onion, such as proper planting geometry and planting time.

Based on the study on growth responses of tropical onion cultivar to photoperiod and temperature in Keren, Eritrea, it was reported that 11.5 h and 12.5 h day lengths induced more leaf production in response to growing degree days (GDD) in all cultivars; Hagaz Red 1, Hagaz Red 2 and Red Creole. However, the 35/18°C (day/night) temperature decreased the leaf number at 11.5 h and 12.5 h day lengths (Tesfay *et al.,* 2011).

2.3.3. Relative humidity

Under high atmospheric water vapor the rate of photosynthesis and water absorption by the plant roots is reduced because of the partial or complete closure of the stomata (Brewster, 2008). Warm, dry atmospheric conditions are important for bulb formation. Dry conditions reduce the occurrence of leaf diseases such as leaf blight (*Botrytis squamosa*) (Msuya *et al*., 2005). Warm and dry conditions during harvesting promote the rapid drying of the leaves, causing the neck of the bulb to dry off quickly that will prevent moisture loss from the bulb and maintaining the firmness of the bulb.

2.3.4 Rainfall

During flowering, seed development and maturity excessive rainfall and very cool condition is undesirable as they lead to disease development and poor seed setting. Good sun shine at the time of full blooming stage will facilitate the activity of beneficial insects for higher rate of cross pollination and seed set. The relative humidity should be lower at the time of seed development (Olani and Fikre, 2010).

2.4 Importance of Onion

Onion is an important bulb crop in Ethiopia it was rapidly becoming popular among producers and consumers. Onion was introduced to the agricultural community of Ethiopia in the early 1970s when foreigners brought it in (Lemma and Shimeles, 2003). Onion is a daily flavouring food in the community. People use onion for daily food. It also used for marketing, hotels and traders (Maru and Gibramu, 2014). Though shallots are traditional crop in

Ethiopia; onions are becoming more widely grown in recent years. It is widely produced by small farmers and commercial growers throughout the year for local use and export market. Onion is valued for its distinct pungency and form essential ingredients for flavorings of dishes, sauces, soup, sandwiches, snacks as onion rings etc. It is popular over the local shallot because of its high yield potential per unit area, availability of desirable cultivars for various uses, ease of propagation by seed , high domestic (bulb and seed) and export (bulb, cut flowers) markets in fresh and processed forms (Lemma *et al.*, 2004).

Ethiopia has high potential to benefit from onion production. The demand for onion increases from time to time for its high bulb yield, seed and flower production potential (Lemma and Shimeles, 2003). Over the last 15 years the total surface area dedicated to onion crop in the world has doubled and presently reaching 2.74 million hectares. Because of its importance, average world yield increased from 12 MT/ha in the early 1960s to 17 MT/ha in 2001. As a result, the increase in the cultivated area and the yield obtained, the world production onion is about 3944million MT per year (FAO, 2011). In Ethiopia, the total area under production reached 24,357.7 hectares and the production was estimated to be over 219,735.3 (CSA, 2014). According to Lemma *et al*. (2006) the production of vegetables is becoming important with the expanding irrigated agriculture and with the growing awareness on the importance of the sector as source of income, improved food security, source of raw materials for industries, generates employment opportunity because it demands large labor force.

Onions are a very good source of vitamin C, B_6, biotin, chromium, calcium and dietary fiber. In addition, they contain good amounts of folic acid and vitamin B1 and K. A 100 gram serving provides 44 calories, mostly as complex carbohydrate, with 1.4 grams of fiber. Like garlic, onions also have the enzyme *alliinase*, which is released when an onion is cut or crushed and it irritates your eyes. Onions contain a large amount of sulphur and are especially good for the liver (http://www.foods-healing-power.com/health-benefits-of-onions.html#sthash.XbNIa9MU.dpuf).

It's also an anti-inflammatory, antibiotic, antiviral, and thought to have diverse anti-cancer powers. Onions can do for your heart: Boost beneficial HDL cholesterol, thin the blood, retard blood clotting, lower total blood cholesterol, lower triglycerides, and lower blood pressure.

One way the antioxidants in onions can protect you against cancer is by reducing the DNA damage in cells caused by free radicals. Onions have also been shown to have a significant blood sugar-lowering action, even comparable to some prescription drugs. The active compound that seem to be responsible for lowering glucose works by competing with insulin for breakdown sites in the liver, thereby increasing the life span of insulin. Onions have historically been used to treat asthma, too. Its action in asthma is due to its ability to inhibit the production of compounds that cause the bronchial muscle to spasm and to relax bronchial muscle. Onions have potent antibacterial activity, destroying many disease-causingpathogens, including *E. coli* and salmonella (http://www.foods-healing-power.com/health-benefits-of-onions. html#sthash.XbNIa9MU.dpuf).

2.5 Onion Production in Ethiopia

In recent years onion is becoming popular vegetable in Ethiopia. Shallots were the traditional alliaceous crop of the Ethiopian high land, but research efforts on onion in the country have resulted in the development of varieties which are currently under wider production in different parts of the country. The most popular of these is ‘Adama Red’ (Lemma and Shimeles, 2003). Moreover, a new cultivar ‘Melkam’ has also been selected from the Indian cv. ‘Pusa Red’, suitable for lowland irrigated production. Onion is grown by both small scale farmers and commercial growers especially under irrigation. Ethiopia has a great potential to produce the crop throughout a year both for domestic use and export market. Its higher yield potential, availability of desirable cultivars for various uses, ease of propagation by seed, high domestic (bulb and seed) and export (bulb, cut flowers) markets in fresh and processed forms is making onion increasingly important in Ethiopia. The major production is in the rift valley areas, besides bulb production, there is a great potential for seed production in these areas. Experiment from Melkassa Research Centre showed the cooler seasons of October to February as suitable period for high seed yield reaching about (1.2 t/ha). The problem behind onion seed production is the poor keeping quality of seeds and loses of its viability within a year, therefore, it is important to produce fresh seed every year (Griffiths *et al.,* 2002).

Onion seed production can bring a high economic benefit for small scale farmers (Lemma and Shimeles, 2003). Onion seed prices are very high which provides a good motivation for prospective commercial producers of seeds. Currently onion seed is being produced by farmers and investors around Melkassa, Awash, along the road to Zeway and its surroundings. The company collects and distributes the seeds in local market. There are two onion seed production methods, the seed-to-seed and bulb-to-seed methods (Olani and Fikre, 2010). The bulb to seed method has advantage of maintaining seed quality, allows rouging off color, misshapen, splits, rotten bulbs, sprout bulbs and require short period of time for seed production. Whereas seed to seed method has the advantage speed up the production practices without affecting the variety's quality (FAO, 2010).

2.6 Seed Production Potential of Onion

Bolting (inflorescence production), can occur in all the *Alliums* vegetables. The inflorescence develops from the shoot apical meristem under appropriate environmental conditions. Underneath the spathe on the broad top of the stem numerous membranous bracts develop each covering several young florets arising on kidney-shaped regions of dividing cells (Tindall, 1983). Looking from the outside towards the center of each floret there develop three members in each of five whorls of floral organs: the outer perianth, the inner perianth, outer stamens, inner stamens and the carpels. These develop as glucose projections, with the outer whorls developing first. The carpels develop as three U-shaped up-swellings on the surface within the inner stamens. These up-swellings grow towards the center and their interned edges meet, fold within themselves and form the ovules, two of which occur in each carpel (Rabinowitch and Currah, 2002). In onion there are commonly 200 to 600 flowers per umbel, depending on cultivar, growing conditions and whether the umbel is formed from the main growing point or an axillary shoot. Similar umbels containing large numbers of flowers are produced by leeks and Japanese bunching onions. Chives typically have about 30 flowers per umbel, rakkyo six to 30 flowers and Chinese chives have approximately 40 white, star shaped, and fragrant flowers in a flat-topped umbel (Brewester, 2008).

Alliums have perfect flowers but, cannot self-pollinate because the male anthers shed pollen before the female stigma is receptive. Therefore, they cross-pollinate via insects (flies and bees) or by manually pollinating (hand-pollinating) the flowers in a controlled environment. Seed producers must keep in mind that varieties of the same species will cross-pollinate with other varieties of the same species (Currah and Proctor, 1990). After pollination, fertilization of ovules starts within 12 h and is complete in 3–4 days. Pollination itself stimulates the initial development of ovules and ovaries. In fertilized ovules, the endosperm nuclei start to divide and cell division and expansion by the embryo occurs 5–6 days later. The embryo reaches its full development when the seed attains maximum dry weight. Initially the endosperm is liquid, and this is termed as the 'milk stage' (Jilani, 2004). But at about 17 days after pollination, cell walls develop within the endosperm and it progresses to the pasty 'dough stage'. At this point, the seed coat starts to turn black. Later on seed attains its maximum fresh weight at about 30 days after flowering. Up to this point, seed dry weight growth is near exponential and seed dry weight is then about half its maximum. The endosperm then becomes solid and the seed reaches its maximum dry weight. After flowering, life completed and on maximum maturity day, the flower turns to give seed. The seeds may be up to 300 per gram (Currah and Proctor, 1990).

There are two methods of onion seeds production which are seed-to seed method and bulb-to seed. Each of them has advantages and disadvantages, while higher seed yield and good quality are those achieved from bulb -to-seed method. Bulb-to-seed allows the seed producers to select specific bulbs that offer the characteristics, and high-quality genetics they're looking for. In bulb to seed method a bulb crop is raised first and seeds are produced from the planted bulbs. However, seed-to-seed production is much cheaper, because there's no need to store bulbs from one season to the next; nor do any bulbs have to be replanted. It is possible where the crop can overwinter as growing plants. In this method, seeds are planted rather than bulbs, in which growing plants are vernalized and induced to flower and produce seeds without going through a bulb stage and it will result in the selection of easy bolting genotypes (Jones and Mann, 1963).

Onions are sensitive to photoperiod and temperature. Both are known to interact to enhance bulbing. Long day are favorable to onion production as this enhance leaf development and formation which, in turn, is directly related to bulb size. Bulb formation and subsequent growth are influenced by temperature and photoperiod (Lancaster *et al.,* 1996). Bulbing, flowering and seed production of onion are controlled by climatic condition such as temperature and photoperiod and seed production is more demanding than bulb production (Rabinowitch, 1990). Temperature greatly influences the flowering of onion. Cool temperature with adequate water supply is most suitable for earlier growth followed by warm, drier condition for maturation. Low temperature (9°C to 17^{o}C) is required for flower stalk development (Singh, 2001).

Length of day affects flowering and bulb formation in certain varieties of onion. Silver Skin variety grown from sets developed normal bulbs and showed the first blossoms under the normal length of day. Under a 10-hour day, however, the plants remained green for 12 months and formed no bulb and no flower. In seedlings, a minimum time of about 40 days at 9^{o}C to 12^{o}C at 16 hours is required. Photoperiods are required to produce an inflorescence initial and at least another 40 days of cool temperature and long photoperiods are required for the inflorescence to enlarge and become visible. Thus, in the field, bolting will be favored if large seedlings or sets exposed to long periods at temperature around 9^{o}C before they start to develop bulbs (Rabinowitch and Brewster, 1990).

Most tropical countries near the equator import much of their onion seeds because temperature is not cool enough to induce optimal flowering. However, there is also possibility of producing onion seed using artificial vernalization (Kimani *et al*., 1994). Study of vernalization under natural condition at high altitude in Kenya using three local and eight introduced onion cultivars showed that onion seed production was possible (Kimani *et al.*, 1994). Onion seed yield is directly dependent on the amount of flowering. Mother bulb treatment at low temperature prior to planting ensures reliable flowering of seed crop (Brewester, 1994). Thus cold treatment of mother bulbs helps producing quality seed.

Effect of vernalization on the yield and quality of onion seed was studied by Ami (2011). Maximum number of seeds (412.22) per umbel, seed yield (91.05 g) per plot, and 1000-seed weight (4.272 g per 1000 seeds) were obtained from 20 g bulbs which were vernalized at 50 ± 100 C for 14 days (Muktadir, 2000). Maximum number of seeds (363.73) per umbel, seed yield (0.46 g) per umbel, seed yield (3.31 g) per plant, seed yield (75.54 g) per plot, seed yield

(755.40 kg) per ha and 1000-seed weight (3.76 g per 1000 seeds) were obtained from 15 g bulbs which were vernalized at 12°C for 21 days.

Vernalization of mother bulbs tremendously affects flowering of onion. In an experiment onion bulbs were exposed to artificial vernalization by exposure to cold at 8°C to 9°C for 6, 9 and 12 weeks in 1990 and 6 and 9 weeks in 1991, the controls were left at ambient temperature. The bulbs were planted at monthly intervals from February to April in 1990 and March to May in 1991 in Zimbabwe. Vernalization gave earlier flowering, the effect being greater against the longer cold treatment. Yield from the control, although later, was of similar weight to that from the vernalized bulbs. These results were observed by Miska *et al*. (1997).

Planting season can also affect onion seed production. The optimum mother bulb planting time has been reported to be between August and October in Ethiopia. Where August, September, and October bulb planting gave high number of flower stalk and seed yield. In the upper Awash and the Lake region, September to February with temperature of 26^0C to 28^0C during the day and 11^0C to 18^0C nights with low humidity were found to be suitable for flower stalk emergence and satisfactory seed set for easy bolting varieties like Adama Red (Lemma, 1998). In north Côte devour, it has been shown that time of planting was critical in order to achieve a satisfactory seed yield, where a cold requirement was defined in terms of hours below a threshold of 15^0C (Currah and Proctor, 1990). The tallest seed stalks were associated with the highest yields and the greatest number of seeds per plant; however, they also noted that this may not be a cause and effect relationship. Seed stalk height was correlated with days required for flowering. It is possible that the flowers on the taller seed stalks were visited more often by bees than those on shorter seed stalks, or that air circulation was better around the taller stalks. It is also possible that the taller seed stalk provide more photosynthetic to the plant causing the weight of each seed to be greater than the weight of seed from plants with short stalks.

2.7 Effect of Planting Date on Onion Seed Production

Planting date is important for proper temperature and photoperiod both of which influence the flowering and number of seed stalks, ultimately affecting the seed yields. Karim and Ibrahim

(2013) reported the impacts of planting time, day length, soil pH and soil moisture on the production of onion.

Planting time for onion is different across the countries due to seasonal variations. EL-Helaly and Karam (2012) conducted a field experiment at Cairo University, Giza Governorate during 2008-2009 and 2009-2010 season, to assess the influence of planting date (November 15, December 15 and January 15) on production of onion cv.Giza 20. Results showed significant effect for most of studied characters. Significantly the highest scape number / plant, scape diameter, main scape length, umbel diameter, seed yield /fed, weight of 1000 seeds and percentage of seed germination were obtained from planting on mid of November.

Khodadadi (2012) conducted a study aimed at determining the planting date and size of the mother bulb effects on some traits which are related to seed on onion Rey variety in Iran during the 2008-2010. The result showed that the planting date significantly affected number of plant emergence plant height and yield per hectare. Significantly the highest seed yield was recorded from the planting date of November 6.

Singh *et al.* (2005) carried out an experiment to study the effect of planting time, bulb size and bulb spacing on plant growth and seed yield attributes of onion cultivar RO-1 at Agricultural Research Station, Durgapur (Jaipur) of Rajasthan Agricultural University (Bikaner). Maximum seed yields (10.95 t/ha) was obtained in October 11 planting, followed by October-1(10.05 t/ha).

Khodadadi (2009) in Iran compared between two planting dates (mid-September and mid-November), and reported the highest seed yield for GholiGhese onion variety planted on mid-September. Rahim *et al.* (2009) reported significant effect of planting time and mulches on agronomic traits contributing for growth and seed yield of onion cultivar Taherpuri. Ud- Deen (2008) conducted an experiment to study the effect of mother bulb size and planting time on growth, bulb and seed yield of onion. Onion bulbs of different sizes (20 g, 15 g and 10 g) were planted at different dates *viz.*, October 30, October 15 and November 30. The large mother bulb and early planting were favorable for getting higher bulb and seed yields. The treatment combinations of large mother bulb (20 g) and 30 October planting time gave the highest bulb (17.52 t/ha) and seed (0.4 t/ha) yield.

Mohanty *et al*. (2001) reported that the planting on November 16 gave the tallest plants (50.52) with the highest number of leaves per plant (14.85), bulb diameter (5.93 cm) , bulb weight (70.78 g) and bulb yield (0.283 t/ha). Further delay in planting resulted in reduced vegetative growth and yield.

George *et al.* (2009) conducted an experiment to study the effect of sowing date, transplanting date and varieties on production of transplanted short day onion varieties in south eastern Georgia's Vidalia growing region. The propensity of some varieties to form double bulbs can be reduced with later sowing and transplanting dates. Sowing the first week of October rather than the fourth week of September and transplanting in December rather than November can reduce double bulbs in some varieties.

Anisuzzaman *et al.* (2009) found that planting time significantly affecting onion development and seed production. According to Ibrahim *et al.* (1996) average number of sprouts, number of scapes and number of umbels/plant were not markedly affected by planting date. The maximum diameter of umbel and longest scape the highest seed yield /plant and best quality seed were obtained from early planting from the planting of (November 25).

The reduction in seed yield as a result of late planting was may be due to flower abortion and low seed yield per plant (El-Helaly and Karam 2012). Malik *et al*. (1999) reported that the highest yield and quality of onion seed was obtained with early planting (15^{th} October) in India. Mosleh (2008) indicated significant influence of planting date on onion growth and seed yield, and early planting was found favorable for getting higher bulb and seed yield in Bangladesh. El-Aweel and Ghobashi (1999) also reported significant seed yield increase with early planting (10^{th} November), which was mainly attributed to increase in weight of seed and number of umbels per plant and 1000 seed weight.

Teshome *et al.* (2014) reported significant ($p<0.001$) effect of bulb size and planting time on seed yield per hectare. According to them, the highest seed yield (1.155 t/ha) was obtained from large bulb size planted on 25 October, followed by medium bulb size planted on the same date (0.983 t/ha) while, the least (0.075 t/ha) was obtained from small bulb size planted on 15 November.

2.7.1 Effect on germination and emergence

Onions are a cool season crop and tolerant to frost. Onion seed can germinate at temperatures as low as 1.4°C to 3.5°C. However, for a germination and emergence percentage of more than 70%, temperatures between 7.5°C and 30°C are needed (Abu-Rayyan *et al.,* 2012). In Germany, an emergence percentage of 90% and more were obtained with soil temperatures ranging between 10°C to 25°C (Kretschmer, 1994). Ansari (2007) reported that a delayed sowing date accelerated the emergence of onion seedlings in Iran. Onion seedlings from seed sown in January emerge after 22 days experiencing an average temperature of 17.7°C, whereas February sown seed emerge after only 10 days experiencing an average temperature of 24.7°C. Seedlings emerge after only 7 days when onion seed was sown in March when there was much higher average temperature (34.7°C) than the earlier sowing dates. These results indicated that higher temperatures can shorten the number of days from germination to emergence. Onions therefore, can germinate at a wide temperature range with the highest germination percentage and seedling emergence between 15°C to 25°C (Ansari, 2007).

Large bulb size (90.78) and planting on 25 October gave the highest germination percentage (97.56), followed by medium bulb size (83.22) and 5 November planting (86.44). Whereas, small bulb size (80.11) and late planting 15 November gave the lowest germination percentage (70.11). Early planting on 25 October increased germination percentage by 39% than late planting (15 November). EL-Helaly and Karam (2012) significant effect of planting date on seed germination and the highest percentage of seed germination was obtained from early planting.

2.7.2 Seedling and vegetative growth

The seedling phase of onions (from the loop up to the cotyledon senescence stage) is a long and slow period of growth and can be as long as 2 to 3 months (Sullivan *et al*., 2001; Brewster, 2008). The relative growth rate (RGR) of onion seedlings (1.00) is almost half of that of other cool season crops such as lettuce (1.91) and cabbage (1.96) and is temperature dependent. However, onion seedlings are the fastest growing of most edible alliums (Brewster, 2008).

Leaf growth and leaf canopy development during the vegetative growth phase from the cotyledon senescence up to the fall of the first leaf stage are temperature related. For leaf growth and leaf canopy development a minimum or base temperature of 6°C is required and at temperatures below 6°C leaf growth will cease. The relative leaf growth rate (RLGR) increase linearly with an increase in temperature from 6°C to 20°C (Brewster, 2008). With a further increase in temperature, growth rate will start to slow down and at temperatures above 26°C it will cease.

2.7.3 Bolting

Bolting is the development of a seed stalk, important for onion seed production but not bulb production (Voss *et al*., 1999). Bolting will also reduce the marketable yield of onion bulbs. Un-timely bolting occurs when the onion plant is exposed to low temperatures (8°C to 13°C) when plants are ready to start forming bulbs (start of bulbing phase). The sensitivity to low temperatures increases with an increase in plant age (Cramer, 2003). The number of leaves has been used to determine a critical plant size at which bolting will be induced under low temperature conditions. According to Khokhar *et al*. (2007) sensitive plant size is when 7 to 10 leaves are formed (i.e., at the end of the first leaf fall and the beginning of bulbing stage). When sowing is done too early in the season, the onion plant will reach the minimum plant size for bulbing when temperatures are still low and will bolt instead of forming bulbs. Sowing date therefore needs to be at a time to prevent plants receiving a cold spell when reaching a minimum plant size resulting in bolting instead of bulbing. However, with late sowing the occurrence of bolting is lower, but plants are still small when bulb formation starts resulting in small bulbs of a poor quality (Cramer, 2003). Therefore, sowing date is one of the important production factors that need to be taken in to consideration for bolting to occur. Agic *et al.* (2007) reported enhanced bolting due to early sowing in the Republic of Macedonia. Late sown onions (1^{st} of September) had the lowest bolting percentage (13.12%) compared to plants sown earlier on 10 and 25 August (34.81 and 27.00%, respectively). Al-Moshileh (2007) reported that early planted onions under central Saudi Arabian conditions resulted in a higher percentage of bolting than late plantings.

2.7.4 Flower development and seed formation

Inflorescence development in onion has three definite successive phases: floral initiation due to low temperature "Thermo phase", growth and development of differentiated inflorescence "competition phase" and the actual flowering and seed production stage "completion phase" that is favored by high temperature and long days (Rabinowitch and Brewster, 1990; Brewster,1994). The progress of flower opening on the umbels is somewhat irregular. Hence, both closed buds and the open flowers at all stages of development are present all over the head at peak flowering in varying proportion in different regions of the umbel (Currah and Ockendon, 1978).

According to a study conducted by Masuda and Hayashi (1956) in Japan, the flowering period lasted for 29 days and during the middle 15 days, 84.9% of the total flowers were open. The number of flower opening on each day was influenced by the number of hours of sunshine on the same day and the previous day. The time and rate of flowering were found to be affected mainly by temperature. Globerson *et al*. (1981), in Israel, reported that flowering in an umbel is completed in 25 to 31 days. They further indicated that onion seed set and development varied with many factors, both environmental and genetic factors affecting the total duration of seed development.

Teshome *et al*. (2014), in Kobo, found early flowering (69 days) from the large bulbs planted on 25 October, while the longest days to attain 50 % flowering were recorded from small bulb size planted on 15 November (82.67). This might be because there was low temperature during early planting which might have contributed for the enhancement bolting and flower stalk development and subsequent flower development, while at late planting the temperature increased which, in turn, `might have delayed bolting and subsequent flowering and maturity. Large bulbs contributed to the plants by giving enough amount of reserved food. Anisuzzaman *et al.* (2009) reported that planting time had marked influence on the number of days required for emergence of 50% flowering and sometimes early maturing is good, as it can escape from bad weather and diseases. Vinney *et al.* (2011) also reported that low temperatures favor bolting.

2.8 Components of Seed Yield

The most important components for onion seed production are umbel size, flower stalk height, number of flower stalks per plant and per plot and flower stalk diameter, which are closely related with the size of mother bulb and cultivars (Prats *et al*., 1996). The number of flower stalks per plant varied from1 to 15 per plant at Melkassa and the terminal number of 50-200 flowers produced per umbel on “Adama Red” depending on the number of shoots axis (Lemma, 1998). Seed yield per plant was positively and significantly correlated with the number of seed stalk per plant and seed yield per umbel (Prats *et al*., 1996; Lemma, 1998).

Umbel diameter was the most important index for seed yield (Prats *et al*., 1996). This character was influenced strongly by base flower stalk diameter. While cause and effect relationship between seed weight and the evaluated components in the inflorescence, it was found that umbel diameter was determining seed yield. This indicated that this character could be a good index for seed yield estimation in onion. According to Teshome *et al*. (2014), the maximum umbel diameter was recorded from large bulb size (5.8 cm) but was on par with the one obtained from medium sized bulbs (5.58 cm). The lowest umbel diameter (5.02 cm) was obtained from small bulbs. The maximum umbel diameter (6.01 cm) was also obtained from those planted on 25 October, followed by 5 November (5.57 cm) and 15 November (4.82 cm). This might be due to higher supply of food materials to the umbel by larger bulb size and early planting also created favorable environmental conditions for earliest flowering and subsequently large umbel size.

Number of seed per umbel was recorded the maximum (515.33) and the least (256.56) number of seeds per umbel were recorded from planted on 25 October and 15 November, respectively. Early planting (25 October) increased seed number per umbel by 100% than the last planting (15 November). Regarding mother bulb size, large bulbs increased seed number per umbel by 26.23% than the small bulbs. In addition to bulb size and planting time, the variation in number of seeds per umbel might be due to flower abortion caused by high temperature, lack of efficient pollinators of all the flowers in the umbel, shortage of nutrition which caused high competition and death of the weak florets in the umbel. Delayed planting resulted in poor plant growth and delayed bolting, moreover, high temperature at scape forming stages might have reduced the number of seed per umbel (Teshome *et al*., 2014).

A study by Sidhu *et al.* (1996) in India, showed that the higher seed yield in some onion cultivars was due to the higher number of seed stalks per plant and to a wider umbel diameter and, hence, the capacity of flowering of the plants was expressed by the umbel size. The seed yield difference among the genotypes ranged from 0.39-1 t/ ha. The number of flower stalks per plant varied from 3-15 with umbel diameter differences of 5-10 cm. The range of flower stalk height was from 76-115 cm; the highest seed yield among the cultivars was correlated with seed stalks number per plant and umbel diameter.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Jari small scale irrigation scheme, Tehuledere district in Northeastern Ethiopia, during the period of September 2015 to April 2016. Geographically the experimental site is located at 11°14N latitude and 39 ^{0}40′E longitude and at an elevation of 1700 m above sea level (m.a.s.l). The mean maximum and minimum temperatures during the growing season were 28.2^{o}C and 6.6^{o}C, respectively. And its mean annual rainfall is 1204.6 mm (JARSC, 2015). Monthly temperature and rain fall data of the trial site during the experiment period is given in Table 2. The soil of the experimental site is sandy loam in texture. The area is regionally well known for the production of onion (JARSC, 2015).

Table 2. Monthly Temperature (^{o}C) and Rain fall (mm) at Jari during the trial period

Months	Temperature			Rain fall
	Maximum	Minimum	Mean	
September	28.4	8.4	18.4	66.43
October	27.2	5.2	16.2	20.8
November	25.8	2.6	14.2	75.2
December	25.8	3.4	14.6	22.4
January	27.4	7.2	17.3	39.2
February	31.0	7.6	19.3	29
March	31.2	6.8	19.0	98.3
April	28.8	11.6	20.2	97.6

Source: Kombolcha Meteorological Directorate (2016)

3.2. Experimental Materials and Design

The experiment was conducted under irrigation from July 2015-May 2016. Onion cultivar ‘Adama Red’ was used for this study. Adama Red is a dark red colored and firm, very pungent, flat globe shaped. It flowers and sets seed very easily, and is widely cultivated in the study area. It is well accepted by both producer and consumer and successfully produces by smallholder farmer and commercial grower scattered in most regions of the country (CSA, 2013).

Recommended bulb size with a bulb diameter ranging from 4.1 - 5 cm (Teshome *et al*., 2014) and dark red colour, firm, very pungent and flat globe shaped free from insect, disease and mechanical injury was selected and used for the study. Hence, bulb-to-seed method was used for this study. Treatments of the experiment were nine planting time set at 15 days interval:1st September (T_1), 16th September (T_2), 1st October (T_3), 16th October (T_4), 31st October (T_5), 15th November (T_6), 30th November (T_7), 15th December (T_8) and 30th December (T_9).

The experiment was laid out as Randomized Complete Block Design (RCBD) with three replications. The size of each experimental plot was 2.1 m wide and 3 m long, having six rows.

3.3 Cultural Practices

Land Preparation: Land of the experiment field was opened on July, 2015. The experimental field was cleared and ploughed four times by oxen and harrowed manually to prepare fine seedbed. The whole field was divided in to three blocks each containing nine plots.

Isolation: Onion is cross pollinated crop, and the seed field was isolated from other onion field by 500 meters to avoid cross pollination by insects.

Planting of Mother Bulbs: The selected bulbs were kept at room temperature up to last planting and the planting was done at every fifteen days interval for successive days of planting. The bulbs were prepared by cutting and removing their one-third top part to facilitate uniform, easy and quick sprouting of growing buds. The lower portion with disc-like stem and roots was dusted with ash to prevent decay due to possible fungal infection.

Planting/spacing: The onion bulbs were planted in rows at spacing of 50, 30 and 20 cm between water furrows/rows on the bed and plants in the rows, respectively (Olani and Fikre, 2010). A distance of 1 m and 1.3 m was maintained between plots and blocks, respectively. Each plot had six rows (ridges), consisting of 90 plants/plot. The middle four rows were used for recording agronomic data.

Fertilizer: Recommended fertilizer rates of urea 100 kg/ha and 200 kg/ha DAP (Olani and Fikre, 2010) were applied. DAP was applied as a single application at the time of planting and Urea was applied in two split doses of equal amounts, at planting and forty five days after planting.

Staking: Staking was provided by using sticks to keep the scapes erect and to protect them from lodging by strong wind and storm.

Irrigation: The field was irrigated three days after planting to facilitate for easy germination of bulbs. Then irrigated every seven days until full flowering and then at every 10 days interval followed by 10-15 days interval near maturity (Olani and Fikre, 2010).

Weeding: Weeding was done from fifteen days after planting up to harvesting within 7-14 days interval at each growing phases.

Harvesting: all umbels per plant do not mature at one time due to difference in the stalks to flowering; hence it was harvested at mature umbels when about 50% black seed is exposed on an umbel. Harvesting was done by hands. When heads are cut was supported in the palm of hand and held between the fingers to avoid seed shattering. The best seed quality is obtained when seed moisture content is between 50 and 65%. Below 50% and lower, umbel shattering occurs. In addition, under 50% seed moisture content results in lower germination and seed weight.

Seed extraction: Seeds were threshed by mowing or rubbing of dried umbels and then cleaning the seeds by winnowing followed by pure seed separation by floatation.

Seed Storage: Dried seed was stored in paper bags in dry and aerated conditions.

3.4. Data Collection and Measurement

Data on different growth, seed yield and seed quality parameters were collected at different growth stages from the middle four rows of each plot. Ten plants from the four central rows of each plot were randomly selected to collect data on plant height (cm), number of leaves per plant, number of scapes per plant, scape height (cm), scape diameter, umbel diameter, number of seeds per umbel, seed yield per umbel (g), seed yield per plant (g), and thousand seed weight (g). On the other hand, data on days to 50% flowering and maturity, and seed yield per plot (g) were collected on net plot size basis. Seed germination (%) test was conducted according to ISTA (1985) at Dessie seed laboratory and seed germination percentage was calculated accordingly.

Growth Parameters

Plant height (cm): Plant height was recorded by measuring from ground to the top of the plant, and was measured before harvesting. The mean of ten plants from each plot was considered.

Number of leaves per plant: Leaves were counted after sixty days of planting from selected ten plants.

Number of scapes per plant: Number of scapes per plant was taken from ten plants in a plot at first harvest.

Scape height (cm): Height was measured from the end of the sheath part to the umbel from ten plants.

Diameter of scape (cm): The diameter of scape was measured at the widest part of scape by using vernier caliper and taken from ten plants.

Days to maturity: Days to maturity was recorded when 50% of the capsule turned brown and started splitting.

Days to 50% flowering: Number of days when 50% of the plants show open flowers.

Yield and Yield Components

Diameter of umbel (cm): Diameter of the inflorescence was measured from ten plants at full flowering stage using vernier caliper.

Number of seeds per umbel: Total seeds obtained from ten umbels were counted and divided by ten.

Number of unproductive scape per plant: Number of un-productive scapes per plant was taken from ten plants in a plot at first harvest.

Weight of seeds per umbel (g): The seed of ten umbels was taken and weighed by using sensitive balance then divided by ten .

Thousand seed weight (g): The weight of random sample of 1000 seeds in grams was recorded as 1000 seeds weight.

Seed yield (g/plant): The mean weight of seeds was taken in grams from ten sampled plants in a plot.

Seed yield (g/plot): The total seed yield was obtained from a plot.

Seed yield (kg/ha): Seed yield per hectare was calculated based on plot yield, and expressed in kg/ha.

Quality Parameters

Germination percentage: The number of germinated seeds, and seedlings were counted from 100 seeds raised on a petridish after twelve days, and the seed germination percentage was expressed as per AOSA (1993).

$$Germination\ Percentage = \frac{Total\ number\ of\ germinated\ seeds}{Total\ number\ of\ seeds\ sown} x100$$

Speed of germination: The number of seedlings emerged was counted from the day of sowing seeds in the medium till the germination was completed. The seed lot having greater germination index was considered as more vigorous. A speed of germination was computed by using the following formula(Agrawal, 1986).

$$\text{Speed of germination} = \frac{Number\ of\ seedlings\ emerging\ on\ day\ 'd'}{Days\ after\ planting}$$

Seed Vigor Index: Root and shoot length (cm) was determined from ten healthy seedlings randomly taken from each replicate at the end of standard germination test(Anonymous, 1993).

Seed Vigor Index I = Germination (%) x [Root length + Shoot length in (cm)]
Seedling Vigor index II = Germination (%) x seedling dry weight (g)

3.5. Data Analysis

All the data was subjected to analysis of variance (ANOVA) using SAS version 9.2 software (SAS Institute, 2008). Differences among treatment means were compared using the Least Significant Difference test (LSD) at1 and 5% probability level.

4. RESULTS AND DISCUSSION

4.1. Growth and Phenological Parameters as Affected by Planting Time of Onion

Data on growth, seed yield and seed quality parameters is depicted on Table 3, Table 4 and Table 5 below. Plant height, number of green leaves per plant, number of scapes per plant, scape length, diameter of scape, days to 50% flowering, diameter of umbel, number of seeds per umbel, weight of seeds per umbel, 1000 seed weight, seed yield per plant, seed yield per plot, seed yield per hectare, germination percentage, and seed vigor index were considered to analyze the effects of planting time on plant phenology.

4.1.1 Plant height and number of leaves

Planting time significantly affected both plant height and number of leaves per plant (Table 3). Plant height ranged from 82.6 cm to 61.8 cm with an average of 74.1 cm. The maximum plant height (82.6 cm) was recorded from plants planted on September 1st and the lowest plant height (61.8 cm) was recorded from plants planted on December 30th (Table 2). Number of leaves per plant ranged from 54.4 to 14.6 with an average of 31.6. The maximum number of leaves per plant (54.4) was recorded from plants planted in September, while the minimum number of leaves per plant (15.4) was recorded from plants planted in December. Therefore, onion planted in September (14.2^{0}C to 18.4^{0}C) showed vigorous vegetative growth compared to those planted in December (14.6^{0}C to 19.3^{0}C). The increase in plant height could mainly be due to early planting which might have provided plants with relatively cooler period compared to the latter eight plantings. The cooler period stimulates cytokine and giberelin accumulation, modifying the hormonal balance and leading the plant to increase the plant development and responsible for elongation of flower stalk (Rakhimbaev and Ol'Shaskaya, 1976). The taller plant height provides more photosynthetic capacity to the plant than shorter height. Similarly, Teshome *et al.* (2014) reported the significant effect of planting dates on plant height, and onion planted in October had maximum plant height compared to those planted in November. Likewise, Mehri *et al*. (2015) reported the significant effect of planting dates on plant height and number of leaves per plant. Onion plants planted in September were longer and with more number of leaves compared to those planted in November. This could be attributed to the increase in the vegetative growth of the onion plant through the effect of planting time, the cooler time was important for the synthesis of different growth component of onion stem and seed. This good foliage indicates higher growth, development and productivity of plant. The tallest plants also produced more number of leaves. On the other hand, Mollah *et al*. (2015) reported that onion plants planted in November were longer and with more number of leaves per plant compared to those planted in October. This difference could be attributed to climatic (temperature) variation among the study site.

4.1.2 Scape number per plant, scape height and scape diameter

Planting time significantlyinfluenced scape number per plant, scape height and scape diameter (Table 3). The number of scapes per plant ranged from 2.7 to 6.3 with an average of 4.4. The height and diameter of scapes ranged from 72.5 cm to 49.9 cm and from 1.48 cm to 0.58 cm, respectively. The maximum number of scapes per plant, scape height and scape diameter was recorded from plants planted early (September 1st). On the other hand onion planted late (December 15th and 30th) had short and minimum number of scapes per plant with small scapes diameter. Therefore, early planting resulted in vigorous plants. In agreement to this result, El-Helaly and Karam (2012) reported maximum number of scapes per plant, scape length and scape diameter from early planting dates. Similarly, Teshome *et al.* (2014) reported maximum scape diameter and scape height from onion plants planted in October compared to those planted in November.

4.1.3 Days to 50% flowering and maturity

Planting time significantly ($p \leq 0.01$) affected both 50% flowering and maturity date of onion (Table 3). Onion planted in October and November required minimum number of days to flower. On the other hand, onion planted in December and September took maximum number of days for flowering. This might be attributed to the coincidence of growth stage of the crop and occurrence of cold weather to induce flower stalk. This might be the reason that in early planting there was low temperature which might have contributed for the enhancement of bolting and flower stalk development and subsequent flower development, while at late planting, the temperature increased which in turn might have delayed bolting and subsequent flowering. The variation in days to flowering among the treatments might be due to the relative low temperature observed in the early growth stages (Table 3) Tesfu and Charles, (2010). Thus, the duration the plants exposed to the low temperature decreased progressively as planting was delayed. This result agrees with finding of Teshome *et al.* (2014) who reported that planting time had marked influence on the number of days required for 50% flowering.

Onion planted in September took maximum number of days to mature. On the other hand, onion planted in December required minimum number of days to reach maturity. This indicates that onion planted in relatively hot climatic (temperature) condition (19.3^{0}C) matured early compared to those planted in relatively cold condition (14.2^{0}C). This result agrees with the findings of Ud-Deen (2008).

Table 3. Effect of planting Time on Growth and Phonological Parameters of Onion at Jari

Planting Time	Plant height (cm)	No. of leaves/ plant	No. of scape/ plant	Scape diameter (cm)	Scape height (cm)	Days to 50% Flowering	Days to 50% maturity
Sept 1st	82.6^{a}	46.7^{a}	6.3^{a}	1.48^{a}	72.5^{a}	79.3^{abc}	130.2^{b}
Sept 16th	80.9^{a}	54.4^{a}	5.0^{bc}	1.25^{b}	70.4^{a}	80.7^{ab}	132.8^{a}
Oct 1st	80.1^{ab}	46.5^{a}	4.7^{cd}	0.88^{e}	69.8^{a}	77.3^{cd}	129.0^{b}
Oct 16th	77.7^{ab}	25.3^{b}	5.9^{ab}	0.99^{d}	64.7^{a}	58.7^{e}	129.6^{b}
Oct 31st	72.5^{abcd}	27.3^{b}	4.0^{de}	1.12^{c}	69.5^{a}	68.0^{d}	124.0^{d}
Nov 15th	69.5^{bcd}	31.9^{b}	3.5^{ef}	0.72^{f}	64.7^{a}	60.7^{e}	126.7^{c}
Nov 30th	76.2^{abc}	14.6^{c}	4.8^{cd}	0.72^{f}	55.3^{b}	81.0^{ab}	120.3^{e}
Dec 15th	65.3^{cd}	15.4^{c}	2.7^{f}	0.61^{g}	53.4^{b}	73.2^{cd}	120.0^{e}
Dec 30th	61.8^{d}	22.5^{bc}	2.7^{f}	0.58^{g}	49.9^{b}	84.3^{a}	110.1^{f}
Mean	74.1	31.6	4.4	0.93	63.4	73.7	124.8
LSD (5%)	11.4	9.8	0.96	0.09	9.2	6.7	2.1
CV (%)	8.9	17.9	12.63	5.96	8.4	5.2	0.95

Means followed by the same letter within a column are not significantly different at 5% probability level.

4.2. Seed yield and quality parameters of onion as affected by planting time

Data presented in Table 4 depicted that planting time significantly influenced onion seed yield and seed yield related parameters such as umbel diameter, number of seeds per umbel, seed yield per umbel, 1000-seed weight, seed yield per plant and seed yield per hectare. Onion planted in September and October had significantly higher umbel diameter, number of seeds per umbel, seed yield per umbel, 1000-seed weight, seed yield per plant and seed yield per hectare compared to those planted in November and December. Similarly, in Bangladesh, Ud-Deen (2008) recorded higher seed yield from onion plants planted in October compared to those planted in November.

4.2.1 Umbel diameter

Planting time significantly influenced umbel diameter. Umbel diameter ranged from 5.8 1cm to 3.3 cm with a mean of 4.8 cm. Mollah *et al.* (2015) recorded umbel diameter with a range of 6.9 cm to 3.0 cm. Teshome *et al.* (2014) reported umbel diameter with a range of 6.0 cm to 4.8 cm. Therefore, umbel diameters recorded in the present study are in the range of previous investigators reports. The highest umbel diameter (5.8 cm) was recorded from onion plants planted on September 1st but was not significantly different from those planted on September 16th, October 1st and November 15th. On the other hand, the smallest umbel diameter (3.3 cm) was recorded from plants planted on December 30th. Therefore, early planting increases umbel diameter compared to late planting. The umbel size of the onion plant is one of the major characters highly demanded for flower and seed production. The plants with wider umbel size can accommodate large number of flowers which later became seeds , thereby increase seed yield; this positive effect of umbel size for high yield further indicated by positive relation with seed yield. Similarly, Teshome *et al.* (2014) recorded the highest umbel diameter from onion planted in October compared to in November. Likewise, in Egypt, El-Helaly and Karam (2012) recorded significantly higher umbel diameter on onion plants planted in November compared to those planted in December and January. On the other hand, in Bangladesh, Mollah *et al.* (2015) reported the maximum umbel diameter from onion plants planted in November compared to those planted in October. This difference might be attributed to the climatic variability among the study sites.

4.2.2 Number of seeds per umbel

Planting time significantly influenced ($p \leq 0.01$) number of seeds per umbel. Number of seeds per umbel ranged from 533.3 to 47.4 with an average of 214.0. Teshome*et al.* (2014) reported 515.3 to 256.6 seeds per umbel. Likewise, Mollah *et al.* (2015) reported 299.9 to 93.0 seeds per umbel in Bangladesh. Therefore, the result of the present study is in agreement with previous findings. Significantly the highest number of seeds per umbel (533.3) was recorded from September 1st planting date. On the other hand, minimum number of seeds per umbel (47.4) was recorded from December 30th planting date. However, it was statistically on par with December 15th and November 15th plantings dates. High temperature during flowering also resulted in flower abortions and hence lower seed yield. So, selection of appropriate months in a given locality is crucial in onion seed production. Teshome *et al.* (2014) reported that, variation in number of seeds per umbel might be due to flower abortion caused by high temperature, lack of efficient pollinators of all the flowers in the umbel, shortage of nutrition which caused high competition and death of the weak florets in the umbel.

4.2.3 Number of unproductive scape per plant and weight of seed per umbel

Planting time was significantly influenced ($p \leq 0.01$) on number of unproductive scape per plant. The maximum unproductive scape per plant (2.7) was recorded from early planting whereas the lowest (0.73) was recorded from late planting.Planting time was highly significantly influenced ($p \leq 0.0$) on weight of seed per umbel. The maximum seed weight per umbel (2.603 g) was recorded from early planting 1st September whereas the lowest weight of seed per umbel (0.13 g) was recorded from December 30th. Early planting is important for the conductive temperature for the development and growth of flowering and seed set. This result is agrees with Teshome *et al*. (2014), El-Helaly and Karam (2012), who reported that maximum weight of seeds recorded from early planting.

4.2.4 Thousand seed weight

Planting time significantly influenced ($p \leq 0.01$) thousand seed weight (Table 4). El-Helaly and Karam (2012) and Teshome *et al.* (2014) reported the significant effect of planting time on thousand seed weight. Thousand seed weight ranged from 3.6 g to 2.2 g with an average of 2.8 g. The maximum thousand seed weight (3.6 g) was recorded from early planting time such as September 1st and September 16th. On the other hand, the minimum thousand seed weight (2.2 g) was recorded from onion plants planted on November 15th and it was statistically on par with those planted on December 15th, December 30th and October 31st. This might be attributed to climatic condition prevailing during the seed filling stage. Therefore, early planting result in well filled seeds compared to late plantings. In addition, the seed filling period of late planting time was significantly shorter than early plantingtime. However, in Bangladesh, Mollah *et al.* (2015) recorded heavy 1000-seed weights from plants planted in November compared to those planted in October.

4.2.5 Seed yield per plant

Planting time significantly ($p \leq 0.01$) influenced seed yield per plant (Table 4). Similarly, Ud-Deen (2008), El-Helaly and Karam (2012), Teshome *et al.* (2014), Mollah *et al.* (2015) reported the significant effects of planting time on seed yield per plant. The average seed yield per plant ranged from 10.0 g to 0.3 g with an average of 3.2 g. The highest seed yield per plant (10.0 g) was obtained from plants planted on September 1st (14.2-18.4^{0}C). On the other hand, the lowest seed yield per plant (0.25 g) was recorded from plants planted on December 30th (14.6-19.3^{0}C) but was not statistically significantly different from those planted on December 15th, November 15th and October 31st. Therefore, early planting time resulted in higher seed yield per plant. Cool temperature for flower development in early planting time and subsequent favorable temperature could have increased the final seed yield per plant. High atmospheric temperature causes early maturity of bulbs before attaining sufficient growth of plant and thereby resulting in low seed yield in onion. The difference in seed yield per plant might be due to the number of scapes per plant, number of seed per umbel and cool temperature for flower development in early planting and subsequent favorable temperature could have increased the final seed yield per plant. Similarly, Teshome *et al.* (2014) reported higher seed yield per plant from onion planted in October compared to those planted in November.

4.2.6 Seed yield per plot and per hectare

Planting time significantly ($p \leq 0.01$) influenced seed yield per plot and hectare and ranged from 322.19 g to 9.33 g and 1032.7 kg/ha to 29.7 kg/ha respectively (Table 4). The maximum seed yield 322.19 g/plot and 1032.7 kg/ha was obtained from September 1st planting. On the other hand, the least seed yield 9.33 g/plot and 29.7 kg/ha was recorded from December 30th planting but the seed yield per ha was statistically on par with December 15th, October 31st and November 15th plantings. In late planting it might be resulted in reduced cycle and less yield, because the plants received stimulus for bulb development before reaching full vegetative development. Therefore, early planting times are suitable for higher onion seed yield at Jari irrigation scheme.

Table 4. Effect of Planting Time on Onion Seed Yield and Yield Component at Jari

Planting Time	Umbel diameter (cm)	No. of seed/ umbel	1000-seed weight (g)	Seed yield/ plant (g)	Weight of seed/umbel (g)	Seed yield (g/plot)	Seed yield kg/ha
Sept 1st	5.8[a]	533.3[a]	3.6[a]	10.0[a]	2.6[a]	322.19[a]	1032.7[a]
Sept 16th	5.3[ab]	395.2[b]	3.6[a]	5.5[b]	1.9[b]	203.5[b]	652.3[b]
Oct 1st	5.2[ab]	351.9[b]	2.9[b]	4.9[bc]	1.5[c]	217.8[b]	691.5[b]
Oct 16th	4.7[bc]	218.4[c]	2.9[b]	4.4[c]	1.3[c]	172.3[c]	552.5[c]
Oct 31st	4.4[bc]	107.5[d]	2.4[cd]	0.8[e]	0.2[e]	31.9[e]	102.2[e]
Nov 15th	5.0[abc]	60.2[e]	2.2[d]	0.4[e]	0.2[e]	11.6[e]	37.4[e]
Nov 30th	4.8[bc]	153.0[d]	2.7[bc]	2.1[d]	0.6[e]	88.2[d]	280.8[d]
Dec 15th	4.3[c]	59.4[e]	2.4[cd]	0.5[e]	0.2[e]	17.9[e]	57.4[e]
Dec 30th	3.3[d]	47.4[e]	2.3[cd]	0.3[e]	0.1[e]	9.3[e]	29.7[e]
Mean	4.8	214.0	2.8	3.2	0.95	119.4	381.8
LSD (%)	0.9	45.88	0.4	0.6	0.19	24.1	73.7
CV (%)	10.9	12.38	8.9	10.9	11.2	11.7	11.2

Means followed by the same letter within a column are not significantly different at 5% probability level.

4.2.7 Germination percentage, speed of germination and seed vigor index

Planting time significantly influenced ($p \leq 0.01$) the germination percentage of onion seeds produced (Table 4). The percentage of germination ranged from 94.3% to 15.3% with overall average of 42.8%. Mollah *et al.* (2015) reported germination percentage ranging from 44 to

84%. Similarly, Teshome *et al.* (2014) reported germination percentage ranging from 77.1% to 97.6%. Therefore, the result of the present study is in agreement with previous research results. The highest germination percentage was recorded from seeds harvested from onion plants planted on September 1st. On the other hand, low germination percentage was recorded from seeds harvested from those planted on December 15th but statistically on par with those planted on November 15th. The reason for increasing the percentage of seed germination in early planting may be due to the highest seed size and seed weight. Therefore, early planting is suitable to produce high quality onion seed at Jari irrigation scheme. Similarly, Teshome *et al.* (2014) recommended early planting date to produce high quality seed at Kobo.

Speed of germination was significantly affected ($p \leq 0.01$) by planting time. Early planted (September 1st) gave the highest speed of germination (7.85), while the lowest speed of germination (1.27) obtained from the late planted (December 14) (Table 5). Seed vigor index I and II were significantly affected ($p \leq 0.01$) by planting time. The maximum seed vigor index I (1117.85) and II (25.26) were recorded from those planted on September 1st, while the lowest seed vigor index I and II (89.69 and 3.72, respectively) were obtained from those planted late (December 15th). This indicates quality difference of seed lots caused by planting time. Early planting gave high seed vigor index I and II. This finding agrees with that of Malik *et al.* (1999), who reported highest seed vigor index I with early planting.

Table 5. Effect of Planting Time on Onion Quality Parameters at Jari

Planting Time	Germination percentage	Speed of Germination	Seed Vigor Index I	Seed Vigor Index II
Sept 1st	94.3a	7.85a	1117.8a	25.2a
Sept 16th	71.0b	5.91b	665.3b	18.0b
Oct 1st	50.3c	4.17c	333.5c	12.54c
Oct 16th	50.7c	4.2c	339.3c	12.55c
Oct 31st	25.0e	2.08e	104.5d	6.3e
Nov 15th	18.0f	1.49fg	91.0d	4.3f
Nov 30th	39.0d	3.23d	337.2c	9.7d
Dec 15th	15.3f	1.27g	89.6d	3.7f
Dec 30th	21.7e	1.8ef	142.7d	5.2ef
Mean	42.8	3.55	357.8	4.4
LSD (5%)	6.1	0.51	69.6	1.7
CV (%)	8.3	8.31	11.2	9.3

Means followed by the same letter within a column are not significantly different at 5% probability level

4.3. Correlation Analysis amongPlanting Time and Different Parameters

Correlation coefficient (r) values computed to determine the relationships between and within the planting time and parameter are depicted in Table 6. The correlation values explain the apparent association of the planting time parameters with each other and clearly indicated the magnitude and directions of the association and relationships.

With increase in time of planting (from September 1st to December 30th) there was increase in temperature. Onion requires ample moisture with cool environment. So the increase in temperature influences flower stalks development, flowering and seed maturation.

Plant height (r= -0.915**) and number of leaves/plant (r = -0.858**) was negatively but significantly correlated with planting time (Table 6). Both plant height and number of leaves/plant could mainly important for photosynthesis and pollination. This implied that the cooler time was important for the synthesis of different growth component of onion stem and seed. This good foliage indicates higher growth, development and productivity of plant.

Umbel diameter (r = -861**), number of seed/umbel (r = -916**), thousand seed weight (r = -0.855**) and seed yield/hectare (r = -895**) was negatively but significantly correlated (Table 6). For that reason, it is possible to say that umbel size of the onion plant is one of the major characters highly demanded for flower and seed production and positive relation with seed yield.

Similarly, Germination percentage(r = -876**), seed vigor index I (r = -787**) and seed vigor index II (r = -872**) was negatively but significantly ($p \leq 0.01$) correlated. The result indicated that the above mentioned parameters can be increased by early planting in which the plant can accumulate high seed yield and quality due to the extended vegetative growth of the plant (Table 6). Bewuketu (2012) reported that parameters can be increased by extending crop cycle by early planting.

Table 6. Correlation Analysis of Planting time among Growth, Yield components, Seed yield and Quality of Onion at Jari

	PT	PTH	NL	NS	DS	SH	FL	DM	UD	NSU	TSU	SYPP	SYPH	GP	SVII	SVIII
PT	1	-0.915*	-0.858*	-0.834*	-0.905*	-0.929*	0.034	-0.901*	-0.861*	-0.916*	-0.855*	-0.881*	-0.895*	-0.876*	-0.787*	-0.872*
PTH		1	0.684*	0.920*	0.786*	0.798*	0.039	0.850*	0.875*	0.879*	0.846*	0.845*	0.890*	0.860*	0.753*	0.849*
NL			1	0.506	0.718*	0.808*	0.188	0.724*	0.686*	0.816*	0.746*	0.716*	0.735*	0.731*	0.660	0.724*
NS				1	0.782*	0.679*	-0.072	0.738*	0.754*	0.816*	0.804*	0.863*	0.877*	0.871*	0.785*	0.863*
DS					1	0.848*	0.035	0.730*	0.708*	0.835*	0.821*	0.828*	0.788*	0.854*	0.822*	0.861*
SH						1	-0.234	0.887*	0.794*	0.726*	0.621	0.669*	0.685*	0.656	0.559	0.655
FL							1	-0.339	-0.074	0.306	0.337	0.226	0.217	0.293	0.365	0.297
DM								1	0.885*	0.714*	0.688*	0.676*	0.710*	0.663	0.553	0.653
UD									1	0.803*	0.730*	0.776*	0.781*	0.754*	0.723*	0.755*
NSU										1	0.948**	0.976**	0.980**	0.973**	0.928*	0.971**
TSU											1	0.925*	0.923*	0.966**	0.922*	0.960**
SYPP												1	0.986**	0.981**	0.954**	0.983**
SYPH													1	0.966**	0.903**	0.961**
GP														1	0.970**	0.999**
SVII															1	0.978**
SVIII																1

* And** Significant at 5% and 1% probability levels, respectively. The decimal numbers without any asterisk are non-significant (P>0.05)

PT-Planting Time, PH-Plant Height,NL-Number of leaves/plant,NS-Number of scape /plant, DS-Diameter of scape,SH-Scape height, FL-Days to 50% flowering, DM-Days to 50% maturity, UD-Umbel Diameter, NSU-Number of seed /umbel,TSU-Thousand seed weight, SYPP-Seed yield /plant,SYPH-Seed yield per hectare, GP-Germination Percentage,SVII- Seed vigor Index I and SVI II-Seed Vigor Index II.

5. SUMMARY AND CONCLUSION

Planting time is one of the most important factors for onion seed production. For production of higher yield of quality onion seed, the bulbs must be planted at optimum time. However, there are no research recommendations pertaining to planting time under the environmental conditions of Jari. The present study was therefore conducted to determine an appropriate time for a better growth, yield and quality of onion seed at Tehuledere, Jari district. The experiment was carried out from September 1st to May 30th 2016 under irrigation condition using Adama Red variety. The experiment consisted of nine different planting times arranged in randomized complete block design with three replications.

Data were recorded both on plant and plot basis for growth, yield, yield components and quality parameters of onion. The finding showed significant differences among the different planting dates with regard to growth, yield and quality parameters, *viz*. number of leaves/plant, number of scape/plant, scape diameter, days to 50% flowering, days to maturity, number of seed per umbel, weight of seed per umbel, thousand seed weight, seed yield/plant. The highest seed yield/plot, seed yield per hectare, germination percentage, speed of germination, seed vigor index I and II were obtained from early planting date; while significantly the lowest values were recorded from late planting. Therefore, based on the finding of the current study, early planting (September 1st) can be used for high yield and better quality of onion seed. The tallest scape height was associated with the highest yields and the greatest number of seeds per plant. The taller scape height might have provided more photo assimilates to the plant causing the weight of each seed to be greater than the weight of seed from plants with short scape. The highest seed yield (1032.7 kg/ha) as well as the highest germination percentage (94.3%) was recorded from onion planted on 1st September. On the other hand, the lowest seed yield (29.7 kg/ha) and germination percentage (15.3%) recorded from onion planted in December. It was evident that plants sown in September 1st exhibited superior performance both in growth, yield and quality characters. This may be because there was enough time for the early planted onion plants to complete both their growth and developmental stages, which in turn enhanced the production and partitioning of photo-assimilates, thus leading to an increase in growth and yield characters. Plants sown late (30th December) had no adequate time to complete their life cycle fully. Several growth, yield component and quality parameters were negatively but significantly correlated with planting time. In this condition planting time and temperature were found to have positive relation, and onion requires ample moisture with cool environment. The increase in temperature influences flower stalks development, flowering and seed maturation.

Based on overall results of the present study, the optimum planting time for seed production of Adama red onion variety at Jari irrigation scheme, Tehuledere district of Northeastern Ethiopia is 1st September. Since this result is based on one season work, in order to give conclusive recommendation, further investigation is needed at Tehuledere district and other locations with similar agro-ecological conditions in the region.

6. REFERENCES

Abdolhossein, A.J. and R.A. Sayed, 2015. Production Potential of Onion *(Allium cepa* L.*)* as Influenced by Different Transplant Ages.

Abu-Rayyan, A., M.W. Akash and G. Gianqinto, 2012. Onion seed germination as affected by temperature and light. *Int. J. Veg. Prod.* 10:37-49.

Agic, R., G. Popsimonova, D. Jankulovski and G. Martinovski, 2007. Winter onion susceptibility to pre mature bolting depending on the variety and the sowing date. *Acta Hort.* 729:271-276.

Agrawal, P.K., 1986. Seed Vigor: Concepts and Measurement.In: Srivastava JP, Simarski LT (eds) Seed production Technology ICARDA, *Aleppo. Syria*, pp. 190-198.

Al-Moshileh, A.M., 2007. Effects of planting date and irrigation water level on onion (*Allium cepa* L.) production under central Saudi Arabian conditions.*Sci. J. King Faisal Univ*. 8:75-85.

Amsalu, A., V. Afari-Sefa, E. Bezabih, F.D. Fekadu, B. Tesfaye and T. Milkessa, 2014. Analysis of vegetable seed systems and implications for vegetable development in the humid tropics of Ethiopia. *International Journal of Agriculture and Forestry*, 4(4):325-337.

Anisuzzaman, M., M. Ashrafuzzaman, M.R. Ismail, M.K. Uddin and M.A. Rahim, 2009. Planting time and mulching effect on onion development and seed production *African J. of Biotech*., 8: 412-416.

Anonymous, 1993. International rules for seed testing. *Seed Sci Technol.* 13:309–333.

Ansari, N.A., 2007. Effect of density, cultivars and sowing date on onion sets production. *Asian Plant Sci.* 6:1147-1150.

Association of Official Seed Analysts, 1993. Rules for testing seeds. *J. Seed Technol*.16:1-113.

Bewuketu, H., 2012. Effect of planting date on tuber yield and quality of potato (*solanumtuberosum* L.) varieties at Anderacha district, South-western Ethiopia

Bosekeng, G., 2012. Response of onion (*Allium cepa* L.) to sowing date and plant population.MSc Thesis, *University of Free State*, Bloemfontein.

Brewster, J.L., 1994. Onions and other vegetable Alliums. *CAB publishing*. UK. 321p.

Brewster, J.L., 2008. Onions and other vegetable alliums. 2nd edn. *CAB International, Wallingford*, United Kingdom.

Coolong, T.W. and W.M. Randle, 2003. Sulfur and nitrogen availability interact to affect the flavor biosynthetic pathway in onion. *J. Amer. Soc. Hort. Sci.* 128:776-783.

Cramer, C.S., 2003. Performance of fall-sown onion cultivars using four seeding dates'. *Amer. Soc. Hort. Sci.* 128:472-478.

CSA (Central Statistical Agency), (2008/2009) Agricultural sample survey: Report on area and production of crops, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency) 2014. Agricultural Sample Survey Volume I, Report on area and production of major Crops, Private peasant holding, *Meher* Season Statistical Bulletin 532, Ministry of Agriculture, Addis Ababa, Ethiopia. 19p.

CSA (Central Statistical Agency), 2015. Agricultural Sample Survey Volume I, Report on area and production of major Crops, Private peasant holding, *Meher* Season Statistical Bulletin 278, Ministry of Agriculture, Addis Ababa, Ethiopia. 22p.

CSA (Central Statistics Agency), 2013. Area and production of major crops.Agricultural sample survey 2012/2013, private peasant holdings, Meher season, Statistical Bulletin 532, Addis Ababa.

Currah, L. and D. J. Ockendon, 1978. Onions in Tropical Regions, NRI, Bull. 35,Chatham, Maritime, Kent UK.

Currah, L. and F.J. Proctor, 1990. Onion in tropical regions.Bulletin 35. *National Resource Institute*. Chatham, U.K. 91-93, 151p.

EARO (Ethiopian Agricultural Research Organization) 2004. Directory of released crop varieties and their recommended cultural practice, Addis Ababa, Ethiopia.

El-Aweel, M.A.T. and A.A. Ghobashi, 1999. Seed production in onion as influenced by dates of planting in the Sultanate of Oman. *Assiut, J. of Agric. Sci*., 30: 43 53.

Elhag, A.Z. and H.M. Osman, 2013. Effect of Plant Spacing on Onion (*Allium cepa* L.)Seeds Quality.*Universal Journal of Applied Science,* 1(2): 52-55.

El-Helaly, M.A. and S.S. Karam, 2012. Influence of planting date on the production and quality of onion seeds*. J. Hortic. Sci*. Ornamental Plants, 4:275=279.

FAO, 1999. FAO Yearbook, production 1998. Food and Agriculture Organization of the United Nations, Rome.51:135-136. Bangladesh, Dhaka.54 p.

FAO-CDMDP, 2010. The FAO-CDMDP Annual Report for the period January –December 2009, FAO-GTFS/ETH/067/ITA, Asella, Ethiopia.

Food and Agriculture Organization (FAO), 2011. *FAO Crop Database*. Food and Agriculture Organization.

FAOSTAT, 2011. Statistics division. Retrieved 08 June 2011.http://faostat.fao.org.

Geremew, A., A. Teshome, T. Kasaye, C. Amenti, 2010. Effect of intra row spacing on yield of three onion (Allium cepa l.) varieties at Adami Tulu agricultural research center (Mid Rift valley of Ethiopia). *J. Hort. Forestr*. 2(1):007-011.

George, E.B., L.T.Reid, C. Jeff; R. Cliff and H.C. Randel. 2009. Sowing date, transplanting date, and variety effect on transplanted short-day onion production. *Hort. Techn.* 19(1): 66-71.

Globerson, D., A. Sharir and R. Eleasi, 1981. The nature of flowering and seed maturation of onions as a basis for mechanical harvesting of the seeds, *Act Hort.*, 111: 99-108.

Griffiths, G., L. T. Trueman, B. Crowther, B. Thomas, B. Smith. 2002. Onions- A global benefit to health. John Wiley and Sons, Ltd.

Hanelt, P. (1990). "Taxonomy, Evolution, and History."In Onions and Allied Crops, edited by D. Haim, L. Rabinowitch and L. James Brewster, 1-26. Boca Raton, Fla.: CRC Press.

Ibrahim, M.Y., A.K. Mostafa, A.M. Hegazy and A.K. El-Kafoury, 1996. Flowering behavior of Egyptian onion cv. Giza 20 affected by planting date.Proc.7 Conf.Athgron. 9-19 Sept. 635-642.

ISTA, 1985. International rules for seed testing. International Seed Testing. *Seed Sci. and Technol.,* 13:299-355.

Jari Agricultural Sub Center 2015. Socio Economical profile of Tehuledere district of Jari.

Jilani, M.S., 2004. Studies on the management strategies for bulb and seed production of different cultivars of onion (*Allium cepa* L.).M.Sc. dissertation, North West Frotier Province of Pakistan.Agriculture University, Peshawar, Pakistan.

Jones, H.A., and L.K. Mann, 1963. Onions and their Allies. London, Leonard Hill. 320p.

Kahsay, Y., A. Fetien and B. Derbew, 2013. *World Journal of Agricultural Research and Food Safety,* 1:034-042.

Karim, R.S.M. and N.R. Ibrahim, 2013: Effect of planting time, day length, soil pH and soil moisture on onion. *International Journal of Biology and Allied Sciences,* 2: 807-814.

Khodadadi, M., 2012. The Effects Of Planting Date And Mother Bulb Size On Quantitative And Qualitative Seed Traits Of Onion Red Rey Variety. *International Journal of Agriculture,* 2:324-327.

Khodadadi, M., 2009. Effects of motheral bulb size, plant density and planting date on the yield and yield components of onion GholeGhese variety Abhar Islamic Azad Univ. Pub., Iran, pp: 28.

Khokhar, K.M., P. Hadley and S. Pearson, 2007. Effect of cold temperature durations of onion sets in store on the incidence of bolting, bulbing and seed yield. *Sci. Hortic*. 112: 16-22.

Kimani, P.M., J.L.W. Kariuki, R. Peters and H.D. Rabinowitch, 1994. Allium for the tropics. *Acta Horticulturae*.358: 34.

Kretschmer, M., 1994. Influence of temperature and soil water capacity on the emergence of onion seeds. *Acta Hort*. 362:181-188.

Lancaster, J.E., C.M. Triggs, J.M. De Ruiter and P.W. Gandar, Bulbing in Onions: Photoperiod and temperature requirements and prediction of bulb size and maturity, 1996 *Ann. Bot*., 78:423-430.

Lemma, D., 1998. Seed production guideline for tomatoes, onion and hot pepper.Institute of Agricultural Research (IAR). 22p.

Lemma, D. and A. Shimeles, 2003. Research experiences in onion production. Research Report No. 55, EARO, Addis Ababa, Ethiopia.

Lemma, D., 2004. Onion Production Pamphlet (Amharic version). EARO, Melkassa Research center.

Lemma, D., and A. Shimels, K. Selamawit and A. Chimdo, 2006. The vegetable seed sector in Ethiopia: Current Status and Future Prospects .EHSS, Proceedings of the Inaugural and Third National Horticultural Work shop, Ethiopia. 1:103-109.

Malik, Y.S., B.K. Nehra and N. Singh, 1999. Effect of planting time, bulb cut and pinching of bolt treatments on yield and quality of onion seed. *Veg. Sci.*, 26: 143-145.

Maru, A.B and A.B. Gibramu, 2014. Constraints of Onion (Allium cepa.Var.cepa L.) Yield Production and Food Preference to Shallot (*Allium cepa*.Var.aggregatum) in the Case of Bibugn Woreda, Amhara Regional State, Ethiopia. ISSN 2224-6088.

Masuda, T. and K. Hayashi., 1956. Studies of the seed rising of onion. Sci. Rep. Fac. Agri. Okayama University, (Japan). 8: 45-54.

Mehri, S., B.R. Forodi and A.K. Kashi, 2015. Influence of planting date on some morphological characteristic and seed production in onion (*Allium cepa* L) cultivars. *Agric. Sci. Dev*., 4(2): 19-21.

Miska, R. L., J.E. Jackson, L. Currah, 1997. Onion seed production trials in the highveld of Zimbabwe. *Acta Hort.* 433: 337-344.

MoARD (Ministry of Agriculture and rural Development), 2009. Rural Capacity Building project.Course for Training of trainers on improved horticultural crop technologies. pp. 5-19.

Mohanty, B.K., and A.M. Prusti, 2001. Performance of Common Onion Varieties in Kharif Seasons. *Journal of Tropical Agriculture*, 39:21-23.

Mollah, M.R.A., M.A. Ali, M. Ahmad, M.K. Hassan and M.J. Alam, 2015. Effect of planting dates on the yield and quality of true seeds on onion. *International Journal of Applied Sciences and Biotechnology*, 3(1):67-72.

Mondal, M.F., J.L. Brewster, G.E.L. Morris and H.A. Butler, 1986. Bulb development in onion (*Allium cepa* L.). The influence of red: far-red spectral ratio and of photon flux density. *Ann. bot*. 58: 197-206.

Mosleh, U.M., 2008. Effect of mother bulb size and planting time on growth, bulb and seed yield of onion. *Bangladesh J. Agric. Res*., 33:531-537.

Msuya, D.G., S.O.W.M. Reuben, L.B. Mbilinyi, A.P. Maerere, T. Msogoya, L.S. Mulungu and R.N. Misangu, 2005. Evaluation of field performance and storage of some tropical short-day onion (*Allium cepa* L.) cultivars. *W. Afr. J. Ecol*. 8:10-18.

Muktadir, M.S. 2000. Effect of planting time, bulb size and vernalization on the yield and quality of onion seed.MS Thesis, Department of Horticulture, BAU, Mymensingh.

National Meteorological Services Agency (NMSA) 2016: Kombolcha meteorological directorate.

Olani, N. and M. Fikre 2010. Onion seed production techniques. A Manual for Extension Agents and Seed Producers Assela Ethiopia.

Okporie, E.O. and I.I. Ekpe, 2008. Effect of photoperiod on the growth and bulbingof two tropical onion (allium cepal.) varieties. *W. J. Agric. Sci.* 4:36-39.

Opara, L.U., 2003. Onion: Post-Harvest Operation. Massey University, Palmerstone North, New Zealand.

Prats, P. A., L. Munoz de Con and M.Z. Fundora, 1996. Influence of onion bulb size and its locality of origin of seed yield. *Onion Newsletter for the Tropics*, 7:25-32.

Rabinowitch, H.D. and J.L. Brewster, 1990. Onions and Allied crops. Vol. I. Botany, physiology and Genetics. CRS Press. USA. 320p.

Rabinowitch, H.O. and L. Currah, 2002. Allium Crop Science: Recent Advances. *CABI Publishing.* U.K. 585p.

Rahim, M.A. 1992. Spices and plantation crops in National Economic. *Proceeding of the sixth National Horticultural Convention and Symposium*, held at Bangladesh Agricultural University, Mymensingh during 1617 April 1992. pp. 24-29.

Rahim, M.A., M. Anisuzzaman, M. Ashrafuzzaman, Ismail, M. Razi, K. Uddin, 2009. Planting time and mulching effect on onion development and seed production. *African Journal of Biotechnology* 8:412-416.

Rakhimbaev, I.R., R.V. Ol'Shaskaya, 1976. Dynamics of endogenous gibberellins during transition of garlic bulbs from dormancy to active growth. *Fisiologye Rasteii* 23:76-79.

Rubatzky, V.E and M. Yamagunchi, 1997. World Vegetables; Principles, Production, and Nutritive Value 2nd ed. *International Thomson publishing*. 804 p.

SAS, 2008.SAS/STAT Version 9.2 User's Guide. AS Institute Inc., Cary, NC., USA.

Saud, S., C. Yajun, M. Razaq, M. Luqman, S. Fahad, M. Abdullah, and A. Sadiq, 2013. Effect of potash levels and row spacing on onion yield. *Journal of Biology Agriculture and Health care*, 3(16): 2013-2118.

Schwarth, H.F. and S.K. Mohan, 1999. Compendium of onion and Garlic Diseases. APS PRESS. USA. 125p.

Sidhu, A.S., J.S. Kumar and M.L. Chadha, 1996. Seed production potential of different genotypes of onion. *Onion News Letter for the Tropics*, 7:38-41.

Singh, M., 2005. Effect of planting time, bulb size and bulb spacing on plant growth and seed yield attributes of onion. Indian Journal of Horticulture, 62(3): 69-73.

Singh, S.P., 2001. Seed production of commercial vegetables. Agrotech Publishing Academy. New Delhi. 186p.

Sullivan, D.M., B.D. Brown, C.C. Shock, D.A. Horneck, R.G. Stevens, G.Q. Pelter and E.B.G. Feibert, 2001. Nutrient management for onions in the Pacific North West. *A Pacific Extension Publication No. 546.* Oregon State University. Pacific North West, United States of America.

Teshome, A., B. Derbew, A. Sentayehu and G. Yehenew, 2014. Effects of planting time and bulb size on onion (*Allium cepa* L.) seed yield and quality at Kobo Woreda, Northern Ethiopia. *International Journal of Agricultural Research*. 9(5):231-241.

Tesfay, S.Z., I. Bertling, A.O. Odindo, P.L. Greenfield and T.S. Workneh, 2011. Growth responses of tropical onion cultivars to photoperiod and temperature based on growing degree days, *African J. Biotech*., 10 (71):15875-15882.

Tesfu, M. and Y. Charles, 2010. Effect of sowing date and planting density on seed production of carrot (*Daucus carota* var. *sativa*) in Ethiopia. *African Journal of Plant Science.* 4(8): 270-279.

Tindall, H.D., 1983. *Vegetables in the tropics*. Macmillan, London. pp. 325-379.

Ud-Deen, M.M., 2008. Effect of mother bulb size and planting time on growth, bulb yield and seed yield of onion, *Bangladesh J. Agric. Res*., 33(3):531-537.

Vanden Berg, A.A., H. De wet and A.F. Coertze, 1997. Onion cultivars.Onions C.L. Agricultural research council, vegetable and ornamental plant institute, Pretoria, southAfrica.

Vianney, M.T.W., R. Albert and T. Zoumbiesse, 2011. Effects of seasons of bulb and seed production on the early bolting of onion (*Allium Cepa* L.) cv violet de Galmi. *J.Applied Biosci.,* 40:2652-2658.

Voss, R.E., M. Murray, K.S. Mayberry and I. Miller, 1999. Onion seed production in California.University of California, Division of *Agriculture and Natural Resources.* California. United States of America.

Weldemariam, S.G., W. Kebede and M. Wassu, 2015. Growth Parameters of Onion (*Allium cepa* L. var. Cepa) as Affected by Nitrogen Fertilizer Rates and Intra-row Spacing Under Irrigation in Gode, South-Eastern Ethiopia, *Agriculture, Forestry and Fisheries*, 4(6): 239-245.

Wickramasinghe, U.L., C.J. Wright and L. Currah, 2000. Bulbing responses of two cultivars of red tropical onions to photoperiod, light integral and temperature under controlled growth conditions. *J. Hort. Sci. Biotechnology*. 75: 304-311.

Wiles, G.C., 1989. The effect of light and temperature on bulb initiation and development in tropical cultivars of onion (*Allium cepa* L.). Ph.D. thesis, Wye College University of London, London.

Ziant, P., A. M. Farooque and M.A. Rahim, 2012. Effects of Vernalization on Seed Production of Eleven Onion Germplasm.

Websites:

http://cms.cnr.edu.bt/cms/files/docs/ Five/vegetables%20production/Study%20guides/

http://www.foods-healing-power.com/health-benefits-ofonions.html#sthash.XbNIa9MU.dpuf

7. APPENDICES

Appendix Table 1. Analysis of variance (mean square) of the data for Plant height, number of leaves per plant, Number of scapes per plant, Scape diameter, Scape height, Days to 50% flowering and Days to maturity of onion

		Mean square						
Source of variation	DF	Plant height	Number of leaves	Number of scape/ plant	Scape Diameter	Scape Height	Days to 50% Flowering	Days to Maturity
Replication	2	7.88	49.37	0.33	0.01	20.01	3.8	0.17
Treatment	8	159.7	622.56	5.03	0.28	210.5	257.8	149.1
Error	16	129	32.03	0.31	0.003	28.3	14.7	1.4
Total	26							
LSD (5%)		11.4	9.8	12.63	0.09	9.21	6.65	2.05
CV (%)		8.89	17.9	0.96	5.9	8.4	5.21	0.9

Appendix Table 2. Analysis of variance (mean square) of the data for Umbel diameter, Number of seed/umbel, 1000 seed/umbel (g), Seed yield g/plant, Seed yield kg/ha and Germination percentage of onion

		Mean square					
Source of variation	DF	Umbel Diameter	Number of Seed /Umbel	1000 Seed Weight	Seed Yield /Plant (g)	Seed Yield kg/ha	Germination Percentage
Replication	2	0.0009	689.51	0.03	0.4	5930.2	15.8
Treatment	8	1.47	91576.09	0.8	32.91	396768.8	2143.8
Error	16	0.27	702.7	0.06	0.12	1814.8	12.6
Total	26						
LSD (5%)		0.9	45.8	0.43	0.6	73.7	6.14
CV (%)		10.9	12.3	8.9	10.8	11.1	8.23

Appendix Table 3. Analysis of variance (mean square) of the data for, Speed of germination, Seed vigour index I and Seed vigour index II of onion

		Mean square		
Source of variation	DF	Speed of Germination	Seed Vigor Index I	Seed Vigor Index II
Replication	2	0.1	1109.5	0.29
Treatment	8	14.8	347653.8	154.4
Error	16	0.08	1620.2	1.03
Total	26			
LSD (5%)		0.5	69.6	1.7
CV (%)		8.3	11.2	9.38

- ✓ Adama red onion cultivar was released in Ethiopia in 1980.
- ✓ Adama red onion bulb was buying from Kobo Girana cooperative farmers in 2015 they were monitored by Sirinka agricultural research center

Appendix Table 4. Characteristics of Adama red onion variety

Onion Cultivar	Maturity Days	Bulb Color	Bulb Shape	Bulb Size(gm.)	Bulb Yield(qt/ha)	Seed Yield
Adama Red	120-135	Dark Red	Flat Globe	65-80	350	10-12

Source: Adapted from Desalegn and Aklilu (2003)

Appendix Table 5.Monthly Temperature (^oC) and Rain fall (mm) at Jari during the last nine years.

	Rain Fall								
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	6.2	18.8	14	49	0	17.3	0	35.7	12.9
Feb	3	87.2	0	29.1	86.9	4.5	0	2.4	24.3
Mar	179	55.8	2	73	154.2	66.6	128.3	95.8	108.3
Apr	142.2	70.4	30.2	116.5	139.3	45	95	13.8	89.5
May	59.1	30.6	34.6	1	117.3	210.4	37	31.2	87.18
Jun	27.6	46.6	26.8	83	11.7	13	65.8	22.1	16.1
Jul	325	365.7	261.7	298.8	544.9	236.8	427.5	382.8	274
Aug	193	257.7	221.2	282.8	617.6	366.9	290.3	266.3	369.9
Sep	167	76.2	196.7	65.6	44.4	46.8	64.8	72.2	100.8
Oct	49.1	19	51.6	53.2	32.5	12.1	21	92	94.9
Nov	0.7	3.7	88.6	9.3	73.4	44.2	0	3.6	13.1
Dec	25.7	0	0	77.4	13.1	0	3	0	4

Source; Kombolcha meteorological directorate (2016)

	Maximum Temperature								
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	25.0	23.9	25.0	24.4	23.8	23.6	25.5	24.5	0.4
Feb	26.1	25.5	25.6	25.8	25.4	26.3	26.9	26.2	24.3
Mar	26.2	26.5	28.7	27.4	25.4	26.4	27.7	27.0	26.9
Apr	26.1	27.0	28.5	27.4	27.9	29.0	27.0	28.0	27.3
May	27.5	30.3	29.6	30.5	28.2	27.5	28.3	29.5	27.0
Jun	29.8	29.3	30.8	31.4	30.6	29.3	30.4	30.3	30.1
Jul	27.1	26.4	28.3	27.5	28.0	27.9	27.2	27.0	28.8
Aug	26.4	26.0	26.5	27.1	25.8	25.9	26.3	24.9	26.0
Sep	26.0	26.3	25.9	27.8	26.3	27.3	26.7	26.3	25.8
Oct	24.0	25.6	25.4	25.8	25.2	25.3	25.3	24.9	24.3
Nov	24.7	24.6	24.1	25.4	24.0	24.4	24.9	23.4	23.3
Dec	24.7	24.6	24.0	23.9	23.5	24.4	25.1	23.5	24.0

Source: Kombolcha meteorological directorate (2016)

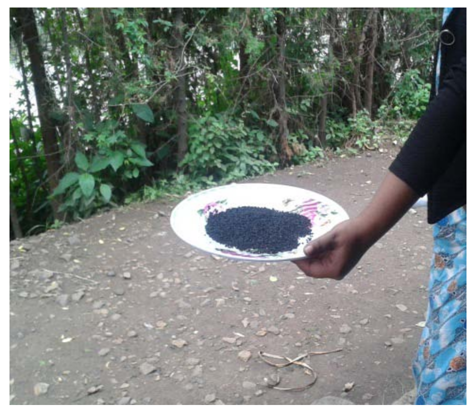
	Minimum Temperature								
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	6.2	9.7	7.3	7.2	7.2	7.8	5.8	6.8	6.9
Feb	6.5	8.1	10.6	6.6	4.2	6.2	9.9	6.8	7.2
Mar	11.3	10.3	6.5	9.0	10.5	9.0	8.1	11.7	9.6
Apr	12.5	12.5	9.8	10.7	12.8	11.3	13.0	12.0	11.1
May	14.7	11.8	12.9	9.8	13.6	13.0	11.6	12.0	11.3
Jun	12.2	12.9	13.0	11.8	12.5	11.6	12.3	12.9	10.6
Jul	14.1	14.2	14.2	13.6	13.7	13.4	13.6	13.4	12.6
Aug	14.1	13.6	13.5	13.2	14.0	13.7	13.6	13.7	12.3
Sep	12.5	11.8	11.9	10.0	12.8	11.4	12.3	12.1	11.5
Oct	8.1	7.0	8.1	8.1	8.9	7.7	7.1	8.0	8.5
Nov	7.8	6.9	6.6	6.3	5.8	4.5	6.2	7.3	7.2
Dec	10.6	4.6	5.0	11.2	7.0	5.7	6.0	3.7	6.3

Source: Kombolcha meteorological directorate (2016)

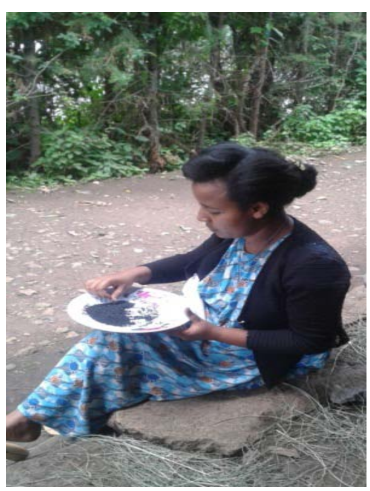
Appendix Figure 1. Onion plant at flowering stage

Appendix Figure 2.Umbel of onion plant

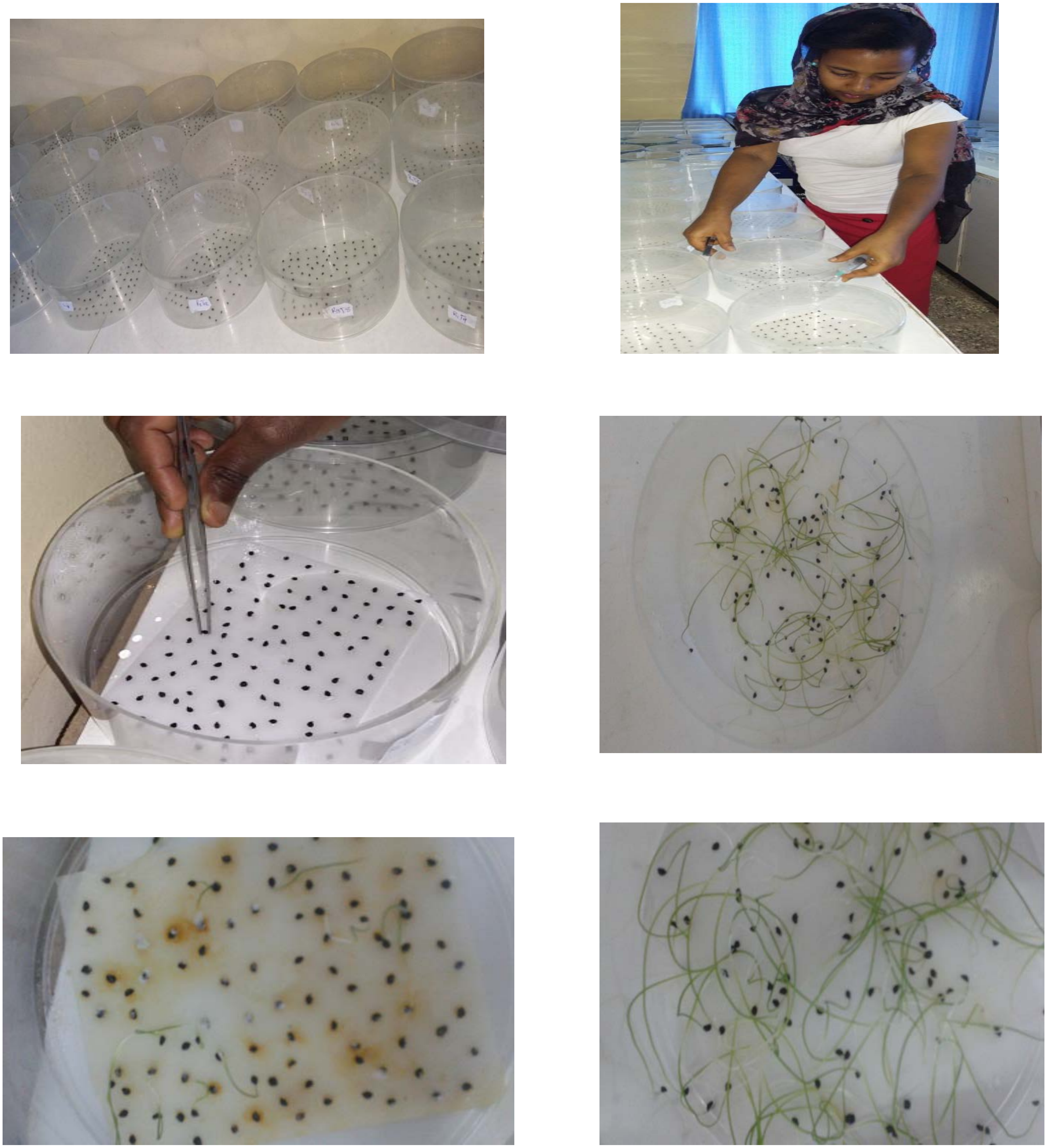
Appendix Figure 3.Dry onion umbel



Appendix Figure 4.Onion seed



Appendix Figure 5. Counting number of onion seeds per plant



Appendix Figure 6. Onion seed quality testing at laboratory and results