MEKELLE UNIVERSITY

EFFECT OF MOTHER BULB SIZE AND NITROGEN FERTILIZER RATES ON GROWTH, SEED YIELD, AND YIELD COMPONENTS OF ONION (*Allium cepa L.*) AT LAELAY MAYCHEW DISTRICT, CENTRAL ZONE OF TIGRAY, NORTHERN ETHIOPIA

By:

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A Thesis

Submitted in Partial Fulfillment of the Requirement for
Master of Science in Horticulture
Department of Dry land Crop and Horticultural Sciences
College of Dry land Agriculture and Natural Resources
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DECLARATION

I, Nirayo Gidey, hereby present for consideration by the Department of Dryland Crop and Horticultural Sciences within the College of Dryland Agriculture and Natural Resources at Mekelle University, my thesis entitled Effect of Mother Bulb Size and Nitrogen Fertilizer Rates on Growth, Seed Yield, and Yield Components of Onion (Allium cepa L.) at Laelay Maychew Woreda, Central Zone of Tigray, in partial fulfillment of the requirement for the Degree of Master of Science in Horticulture. I sincerely declare that this thesis is the product of my efforts, and no other person has published a similar study that I might have copied, and at no stage will this be published without my consent.

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BIOGRAPHICAL SKETCH

The author Nirayo Gidey was born on June 30, 1990, in Axum, Central Zone, Tigray, to his father, Gidey Demoz, and Kebedech Gebretadewos, her mother. From 2000 to 2008, he attended Kisad Aqui Elementary School for elementary education (grades one through eight) and Knife Gebremedhn School for secondary school and preparatory (grades 2009 to 2013). He joined Mekelle University's College of Dry Land Agriculture and Natural Resources in 2005, after finishing his primary and secondary schooling, and in July 2015. He earned his Bachelor of Science (BSc) in crop science.

His first job was as a soil fertility and agro-forestry expert at North West Tigray, Tselemti Woreda Office of Agriculture and Rural Development, where he worked until April 29, 2018. In April 2017, he started working as a researcher in horticulture at Tigray Agricultural Research Institute (TARI), where he remained until 2019, when he joined the Mekelle University to pursue a program leading to a Master of Science (MSc) in horticulture.

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ACRONYMS AND ABBREVIATIONS

AARC	Aksum Agricultural Research Center
ANOVA	Analysis of variance
CRV	Central rift valley
CSA	Central statistics agency
CIMMYT	Center of International Maize and Wheat Improvement
CV	Coefficients of variation
DW	Dry Weight
DAP	Day after planting
EIARC	Ethiopia institute of Agricultural Research Center
FAO	Food and Agricultural Organization
Ha	Hectare
LSD	Least significant difference
m.a.s.l	meter above sea level
MRR	Marginal Rate of Return
MoARD	Ministry of Agriculture and Rural Development
NPK	Nitrogen phosphors potassium
RCBD	Randomized Complete Block Design
t	Tons
TARI	Tigray Agricultural Research Institute

DEDICATION

I dedicate this thesis to my dear wife (Genet Weldemariam) for her advice and for treat me with love and care and for her partnership in the success of my life.

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ABSTRACT

Inappropriate uses of bulb size and without or with very low rates of nitrogen fertilizer application are major factors constraining onion seed production in Tigray. Therefore, a field experiment was conducted during 2023/2024 in Laelay Maychew Woreda Central Zone of Tigray to study the effect of mother bulb size (3-4 cm), medium (4.1-5 cm), and large (5.1-6 cm) and nitrogen fertilizer rates (0, 23, 46, 69, and 92 kg ha-^{1}*) on growth, seed yield, and yield components of onion. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The results revealed that all growth and yield components were significantly (*$P < 0.05$*) influenced by the main effect of bulb size and nitrogen and nitrogen only***.*** *The tallest plant heights (cm), flower stalk length (cm) and Maximum numbers of flowerstalks per plant were obtained from the plant that received 69 N kgha*$^{-1}$* as well as those large bulb sizes (5.1-6 cm).However highest values of flower stalk diameter (mm), wider umbel diameters (mm) and number of seed per umbel (550) were found from the plant treated at the rate of 92 kg ha*$^{-1}$* of N and medium mother bulb size (4.1-5cm).The maximum seed weight per umbel (2.32g), thousand seed weight (3.86g) and seed yield per plant (17.20g) and seed yield per plot (1197.91g) were obtained from the combination of large (5.1-6 cm) mother bulb size with 69 kg of Nha*$^{-1}$*.The shortest days to 50% flowering and maturity were found from the treatment combination of 69 kg ha*$^{-1}$* with 5.1-6 cm mother bulb size. The highest seed yield per hectare (*1983.25 *kg ha*$^{-1}$*) was obtained from the treatment combination of 69 kg and 5.1-6 cm mother bulb size. As the partial budget analysis revealed that maximum net field benefits (*4550120*) Ethiopian Birr with Marginal rate of return (*56.88*) were obtained from a bulb of 5.1–6 cm size grown with an application of 69 kg N ha*$^{-1}$*. Hence, for high yield and economically feasible seed yield of onion, the treatment combination of 5.1–6 cm bulb size and 69 kg ha*$^{-1}$* of N are recommended for the study area. To make a final recommendation, it is advised to conduct the experiment again in the study area, as it was conducted for only one season and one site.*

Key words: Onion, Mother Bulb size, Nitrogen, Seed yield, Laelay May chew

1. INTRODUCTION

1.1. Background and Justification

Onions (Allium cepa L.) belong to the genus Allium and are members of the Alliaceae family (Beji et al., 2023). The origin of onion is thought to be in central Asia and most likely migrated to the Near East, and areas around the Mediterranean Sea are secondary centers of development (Malik M.N., 2000). Allium cepa is the most widely cultivated species, unlike other edible species of Allium, only has a single bulb and is usually produced using true botanical seeds. Onion has been cultivated for more than 5000 years and is not known to exist in the wild. In terms of cultivation, onion ranks second next to tomato (FAO, 2018).

Onion is a very important vegetable crop as a source of food for human beings. It is valued for its distinct pungency and forms an essential ingredient for flavoring varieties of dishes, sauces, soups, sandwiches, snacks as onion rings, etc., and is a cash crop both for local and export earnings and serves as an area of employment for many people due to its intensive culture(Desjardins, 2008).Onion has also therapeutic qualities, which are well recognized in the control and treatment of cardiovascular disease, diabetes, cancer, asthma, and antibiosis (Demis et al., 2019). The developed bulb includes some protein, significant amounts of carbohydrates, and vitamins A and B (Augusti, 1990).

Onions can be grown under a wide range of climatic conditions but are more successful under mild season without extremes of heat or cold and excessive rainfall (ZerihunZena, 2017). Onion has shorter routes'' and requires well-drained soil that is rich in organic matter. Onion is grown in many different zones, starting with the relatively arid and hot ones. There are various onion varieties that vary in latitude based on the crop's sensitivity. It is day length sensitive; several onion types exist depending upon the latitude at which they grow (FAO, 2013). The world yield average of onion is about 19.7 tons/ha (Yeshiwas et al., 2023, Gelaye et al., 2024). The largest global producers of onions include China, India, the USA, and Turkey (FAOSTAT, 2023). Ethiopia has enormous potential to produce the crop throughout the year, both for domestic use and the export market. Onion is one of the most important cash crops in Ethiopia, which contributes to the commercialization of the rural economy and provides many off-farm jobs (Lemma and Shimeles, 2003, Nikus and Fikre, 2010, Demis et al., 2019).

Seed production is a vital part in onion growing and is a highly specialized business requiring particular knowledge and training. About 9,745.36 tons of onion seed was produced in the world in 2011 (FAO, 2013).In Ethiopia, around 36.4 million hectares of land are allocated to onion cultivation, resulting in a harvest of approximately 346,048.1 tons of bulbs with a productivity rate of 8.9 tons per hectare. Most of the onion production (73%) is consumed by farm households, while 26% is sold in the market and 1% is used for seed purposes(Gelaye et al., 2024; Yeshiwas et al., 2023). Seed yield per hectare was 1.3 tons (Lemma and Shimeles, (2003). As compared to the world average, Ethiopia's onion seed yield per hectare is very low. 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 (Nikus and Fikre, 2010). Likewise, the demand for onion seed is increasing. However, seed supply is insufficient, its price is increasing every year, and onion seed available in the market is poor in quality (Nikus and Fikre, 2010). Onion seeds lose their viability within a year and have a limited shelf life. Smallholder farmers all around the country started producing onion seeds gradually as a result of these challenges. Onion seed yield is influenced by many factors, among which lack of adaptable high yielding varieties, bulb size, spacing, lack of proper soil fertility management practice, and other agronomic practices, diseases and insects etc. Nitrogen plays a significant role in improving the productivity and quality of vegetable seed. Onions are the most susceptible crop plants to extracting nutrients, especially the immobile types, because of their shallow and unbranched root systems (Brewster, 2008; Rizk et al., 2012). Nitrogen comprises 1–5% of total dry matter of plants, is a constituent of many fundamental cell components, and plays an important role for optimum yield onion seed (Bungard R et al., 1999). Nitrogen has been found to increase the number of umbels per plant, number of florets per umbel, umbel size, and seed yield (Amare et al., 2020). An excellent supply of nitrogen stimulates root growth and improvement as nicely as the uptake of other vitamins. Bulb size determines the vigor of the reproductive phase and the number of reproductive shoot initials. This is directly related to the number of seed stalks and subsequent seed yield. The determination of the best combination of these can be used to improve onion seed production Basnet et al, (2015).

The effect of different nitrogen fertilizer rates and mother bulb sizes on onion seed production was studied and reported by several scholars in different parts of the world. For example, vigorous umbels larger than 5 cm in diameter, a high number of flower stalks and nearly twice the seed yield (695 kg/100 ^{m2}) of small size bulbs were produced by big mother bulbs larger than 4.1 cm in diameter (Lemma & Shimeles, 2003).According to Ahmedet al., (2021), significant variations due to different bulb sizes were observed in respect of seed yield ha^{-1}. The large size bulb produced the highest seed yield (1563.33 kg ha^{-1}), which was followed by medium size bulbs (1383.33 kg ha^{-1}), and small size bulbs produced the lowest yield (1193.33 kg ha^{-1}). Similarly, Teshome et al. (2014) reported the highest seed yield (1.155 t/ha^{-1}) was obtained from the large mother bulb size. Taking into account that larger bulbs produce more seeds, using large bulbs will require a very high seed rate (Khokhar, 2009).

A number of studies have also been carried out to evaluate the effect of N levels on the seed yield of onions. According to Lemma and Shimeles (2003), 92 kg Nha^{-1} was determined to be sufficient for onion seed production in Melkassa conditions .Basnet et al. (2015) obtained a relatively higher rate of nitrogen (160 kg N ha^{-1}) to be optimum for seed production in Bangladesh. Furthermore, in Shewa Robit, the highest seed yield per hectare (879.4 kg) was recorded from 114 N kg ha^{-1} fertilizers (Amare et al., 2020). However, these recommendations cannot be directly adopted for the soil and growing conditions of the Central Zone of Tigray, which are different from the conditions in Melkassa and other regions.

Recommendation on the N rate could not be universal. Therefore, to optimize onion seed productivity in the study area, a specific package of recommendations for nitrogen fertilizer and mother bulb size is required.

1.2. Statement of the Problem

In the Tigray, onion is one of the widely grown vegetable crops, and the area also has a suitable climate for onion seed production. Similarly, La'elay Maichew district has a suitable climate for onion bulb and seed production. There are many production constraints responsible for low yields in the districts. Among these constraints, inappropriate use of inorganic fertilizer and improper use of mother bulb size were the most important management factors. Study on nitrogen fertilizer rate and mother bulb size selection to improve seed yield is limited. Different agronomic practices are undertaken to produce onion seed in the Tigray region. The blanket recommended rates of fertilizers both for seed and bulb production are 200 kg ha^{-1} of P_2O_5 and 46 kg ha^{-1} of N (Nikus and Fikre, 2010). However Mostly farmers in the study area are using lower than 46 kg N ha^{-1} fertilizer rates or below the blanket recommendation. Because they don't know the optimum rate of N and apply a very small amount, which could not have a significant function for onion seed production. Others do not use fertilizer because they believe that the bulb itself is sufficient for seed production. This shows no specific nitrogen levels are applied by producers for onion seed production, and also no experiments have been done to determine whether the recommended fertilizer for bulb production is good as for seed production in terms of seed yield.

Similarly bulb size is one of the most important factors and directly influences seed yield. Seed production of onion is grown at the recommended bulb size of 3–4 cm (Lemma and Shimeles, 2003). However, farmers in the district cannot apply even this recommendation. Farmers do not use optimum bulb-sized onions to produce onion seed. They simply plant bulbs without selecting the proper size because mother bulb is too expensive during planting time from September and October. For the reason that their production is low, they stop producing seeds and buy seed at high prices, and dependent on seed produced in other parts of the country or imported from abroad. Keeping all these above facts in view, it is necessary to test different mother bulb sizes and with different N fertilizer rates to attain maximum seed yield for the specific agro-ecology. This is because any agronomic practices recommended somewhere may not perform in the new areas due to difference in agro-ecology. Given these considerations, the study was aimed to investigate the optimal nitrogen fertilizer rate and mother bulb size to enhance onion seed yield in the Central Zone of Tigray.

1.3. Objectives

1.3.1. General Objective

The general objective of this study was to evaluate and determine the effect of nitrogen fertilizer rate and mother bulb size of onion on seed production of Bombay red onion varieties at Laelay Maychew district.

1.3.2. Specific Objectives

- To assess the effects of different nitrogen fertilizer rates and mother bulb sizes on growth, yield, and yield components of onion seed of the Bombay red onion variety.
- To evaluate the interaction effect between mother bulb size and nitrogen fertilizer rate on seed yield of onion.
- To determine economically optimum nitrogen fertilizer rate and mother bulb size that improves seed yield of onion.

1.4. Research Hypothesis and Questions

1.4.1. Research Hypothesis:

- Different rate of nitrogen fertilizer and mother bulb size will significantly influence the growth, yield and yield component of onion seed in central zone of Tigray, with specific interaction between these factors affecting outcomes.

1.4.2. Research Questions

- What are the effects of various nitrogen fertilizer rates on the growth parameters and seed yield of onion?
- How does the size of mother bulb interact with different nitrogen fertilizer rate to affect the growth, yield and yield component of onion seed?
- What is the optimal combination of nitrogen fertilizer rate and mother bulb size for maximizing growth and seed yield of onion?

1.5. Significance of the Study

This study provided significant information on seed production method and technology, mainly on nitrogen fertilizer rate and mother bulb size in Tigray, particularly in the study area. Specifically, the importance of this study is for farmers, seed producers, investors, and researchers. It suggests ways of solving the challenge of seed production methods at the district level. It also provides a foundation for future research endeavors related to this topic.

2. LITERATURE REVIEW

2.1 Origin and Distribution

Onion (Allium cepa L.) belongs to the genus Allium of the family Alliaceae, which was believed to be native in central Asia, being the center of domestication and variability, from where it was spread first across the world and has been cultivated for over 4700 years as annuals for bulb production purposes (Brewster, 2008). It ranks second only to tomatoes in terms of global production. With a long and varied history, onion is believed to be among the first plant species to be domesticated during the era of ancient human civilization. For instance, archeological evidence suggests that onion domestication took place over 4000 years ago.

The practice of onion cultivation and its subsequent worldwide spread is thought to have closely followed human migration pattern and tread (McCallum et al., 2008). Owing to their unique flavor, health-promoting properties, and culinary versatility, onions have become a staple in human diets and cultures over millennia, adding flavor and aroma to countless dishes (Benke et al., 2022). Globally, more than 60 million tons of onion yield are produced annually, with an average yield of about 19.7 tons/ha (Yeshiwas et al., 2023).India is the world's largest onion producer, harvesting 26738 metric tons annually. China produces 23660 metric tons, annually using 9.2 million hectares of land dedicated to only growing onions. In the third place, the United States produces 3,821 metric tons of onion every year, which is significantly lower than China and India (FAOSTAT, 2023). Additionally, high onion productivity has been recorded in countries such as Republic Korea and Guyana. The diversity of onion cultivars varies across different geographical locations and agro-climatic conditions, influenced by factors such as climate and soil suitability, as well as market preference. The edible component of the onion plant, encompassing both green foliage and the bulb, is treasured not only for its culinary application but also for its nutritional and medicinal properties.

2.2. Botanical Characteristics of Onion

Allium cepa, including shallots, has a diploid chromosome number (2n = 16), which differs significantly in storage organs such as foliage, leaves, flowering time, color, and opening order (Gelaye et al., 2024). Onions are being cultivated for bulbs and inflorescences that have been closely adapted to temperatures and photoperiods. Onion belongs to the genus Allium, family Alliaceae, which has about 750 species, among which onion, Japanese bunching onion, leeks, garlic, and shallot are the most important edibles, Rabinowitch and Currah (2002).

It is a biennial plant that is grown as an annual for bulb production. The bulb produced in the first season consists of swollen leaf bases, and the inner ones are fresh and act as food reserves. The outer leaves are dry and scaly and protect the inner ones. At first the inflorescence is enveloped by a spathe, which later splits, exposing the florets. The scape is at first solid, but later it becomes hollow. It is swollen midway. The flower has six perianth segments, six stamens, and a single pistil that is composed of three fused carpels with three locules(Currah and Proctor, 1990).The stem internodes that are between the last foliage leaf and the spathe are known as the scape. The scape is originally solid but ultimately becomes hollow and thin-walled due to differential growth. The quantity of lateral buds that sprout determines how many scapes will eventually emerge. Each scape bears a spherical umbel that has a diameter ranging from 2 to 15 cm. The umbel is made up of numerous blooms in different stages of development; typically, 200–600 tiny individual flowers make up the umbel. Four weeks or more may pass during the blossoming phases. With six white petals, six stamens, and a three-carpel pistil, the flowers are perfect. Nectar from flowers attracts pollination insects, primarily honey bees. Alliums have beautiful flowers, but because the male anthers release pollen before the female stigma becomes receptive, alliums are unable to self-pollinate. As a result, they cross-pollinate by insects like bees and flies or by artificially pollinating the blossoms in a controlled setting. Ovule fertilization starts 12 hours after pollination and takes 3–4 days to complete.

When the seed attains its maximum dry weight, the embryo is fully developed. The first stage, known as the "milk stage," is when the endosperm is liquid (Jilani, 2004). However, the endosperm begins to form cell walls around seventeen days following pollination, at which point it enters the pasty "dough stage." The seed coat is now beginning to become black. After flowering, the seed will attain its maximum fresh weight about 30 days later. The growth of seed dry weight is nearly exponential up to this stage, after which it approaches half of its maximum. At that point, the seed reaches its maximum dry weight, and the endosperm solidifies. The seeds are tiny, irregularly shaped, black, and about 300 seeds weigh one gram (Currah and Proctor, 1990).

2.3. Production Status of Onion in Ethiopia

Onion is an important bulb crop in Ethiopia and was introduced to the country before 53 years and quickly became popular among producers and consumers (Gelaye et al., 2024). In the early 1970s, foreigners introduced onions to Ethiopia, despite shallots being a traditional crop, and recently, onions have gained popularity and become more widely cultivated in the country Etana et al. (2019).Onion is a high-value bulb crop that has been produced by smallholder farmers and commercial growers for both local and export markets in Ethiopia (FAO, 2018). It ranked second in production of all vegetable crops next to tomatoes (FAO, 2018).The expansion of water harvesting structures in small-scale farmers has been reported to contribute significantly to the progress of onion production. This crop can be cultivated twice per year, both under irrigation and rained conditions in different parts of the country.

According to the central statistical agency (CSA) report of 2021, 346,048 tons of onion yield were harvested from 38,952.58 hectares of land in Ethiopia. The average onion production intensity in Ethiopia is 8.9 tons per hectare; lower than global averages of 19.1 ton per hectare, 35.5 tons per hectare in Egypt, and 18 tons per hectare in Sudan (FAO, 2023). Within Ethiopia, the Oromia Region leads in onion production with average yield of 19.32 tons per hectare, followed by the Amhara Region. The Amhara

Region contributes around 50% of the national onion production, with average productivity of 12.3 ton per hectare. Different vegetables and spices have been introduced and cultivated mostly in the lowlands or flood plains, where sources of water and soil fertility are relatively higher. Onion is one of the high-value vegetable crops produced both in rained irrigation.

2.4. Climate Requirement for Onion seed Production

Onion seed production, influenced not only by genetic factors but also by environmental factors such as temperature, daylength, rainfall, and soil conditions, presence of beneficial insects, is a critical factor for onion seed production at any stage of crop seed development.

2.4.1. Temperature

Temperature greatly influences flower stalk development and seed set. A cool temperature with adequate water supply is most suitable for earlier growth, followed by a warm, drier condition for maturation. Low temperature (9–17 oC) is required for flower stalk development (Singh, 2001). Onion varieties are well-grown in low and mid-altitude areas (700–1800 m.a.s.l.), but onions can grow up to 2000 m.a.s.l. Ideal temperature for bulb production is 180°C to 240°C during the day and 100°C to 120°C at night. For bulb production, it can go higher beyond these ranges. After bulb develops, cool weather with ample moisture supply is important for flower stalk initiation (Olani and Fikre, 2010). High temperatures during flowering also result in flower abortions and hence lower seed yield. So, selection of appropriate months in a given locality is crucial in the onion seed production venture. It is also helpful to know the specific condition of the crop varieties. For example, Bombay and Adama Red flower and produce a higher seed yield under a moderately lower chilling temperature.

According to Tekle et al. (2019), September 30 found to be an appropriate planting time for the mother bulb to produce a high and quality seed yield of onion in the Central Zone of the Tigray region. Temperature can affect onion plants at all stages of growth and development (Coolong and Randle, 2003). To obtain a germination percentage of at least 70%, a 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. Temperature and photoperiod are two factors that affect onion bulbing, flowering, and seed production; seed production is more demanding than bulb production (Rabinowitch, 2010).

2.4.2. Day Length

Day length is a measurement of the number of hours of light and dark in a 24-hour period. The reproductive cycles of many crops are governed by the amount of light and darkness that they are exposed to it in a 24-hour period. 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, the 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, 1984).

Day length sensitivity is variable among crop species and the varieties within them. Onion varieties are classified as long, short, or intermediate day varieties ranging between 12 and 16 hours depending on how many hours of daylight they require for bulb formation, flowering, and seed set (van den Berg et al., 1997). 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° and 60° latitude (Van den Berg et al., 1997).

When long-day cultivars are grown in short-day climates, they may never flower and set seed because days never get long enough to trigger the biochemical changes that start these processes. If they do not manage to flower and set seed in a short-day climate, the timing may be too late to allow for full maturity of the seed before fall. Conversely, if cultivars are 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). Inflorescence initiation in growing seedlings is influenced by photoperiod, nitrogen nutrition, and daily radiant exposure, as well as by temperature.

2.4.3. Rainfall

The two most critical stages in onion seed development are precipitation, which can be damaging during flowering and pollination, and final drying down. If it is too rainy during flowering, the activity of pollinating insects may be reduced. Honeybees are especially sensitive to these conditions and will not fly when it is too cool or wet. This is particularly important for onions as a cross-pollinated crop that relies on insects for successful pollination. Excessive rainfall and very cool conditions are also undesirable during flowering, seed development and maturity as they lead to disease development and poor seed setting. Good sun shine at the time of the full blooming stage will facilitate the activity of beneficial insects for a higher rate of cross-pollination and seed set. The relative humidity should be lower at the time of seed development (Olani and Fikre, 2010.

2.5. Cultural Requirement for Onion Seed Production

2.5.1. Cultivar

Because onions have been cultivated for so long and because their bulb and inflorescence development must be closely adapted to the temperature and photoperiods that prevail where they are grown, there exists a large range of cultivars and land races developed over the centuries to fit the diverse climate and food preferences of the world (zerihun zena,2017). Cultivars are developed based on the different characteristics of foliage (leaf length and leaf erectness); shape of the bulb (globe, flattened globe, flat top, and cylindrical); uniformity of the bulb shape; skin color of the bulb (white, yellow). nature of the inflorescent, including fertility, the number of flowers in the umbel, the petal and anther color in order to attract pollinating insects, and the presence or absence of bulbils (small bulbs) in the inflorescent. Currently, because of its earlier maturity and better bulb output, Bombay red is the most commonly grown onion variety in the nation when grown under irrigation. Rainfall during the maturation period of this cultivar will allow it to rot in the field, making it undesirable for production under rain-fed conditions. On farmer's fields in central rift valley zones, yields of Bombay Red up to 40 tha^{-1} have been reported; this is mostly because of its tolerance to greater plant populations (it can successfully produce good-sized bulbs at spacing as low as 4 cm between plants). However, Adama red can only provide large-sized bulbs when plants are spaced more than 6 cm apart. In contrast to the former, Adama red can be grown in rainy environments since it can withstand rot root caused by rain during the maturity stage. Cultivars used in temperate regions generally have a longer vernalization requirement, whereas those developed in the tropics have a shorter vernalization period requirement (George, 1985). An average of 3 months of storage at 10 °C is sufficient to induce flowering in most cultivars (Peters, 1990).

2.5.2. Vernalization Temperature and Duration

High temperature or lack of cool weather conditions to induce flowering is the main challenge of onion seed production in tropical countries. Due to this reason, many countries have to import onion seed from sub-tropical or temperate countries where the winter season provides the chilling requirement for flowering (Peters, R. 1990). Flowering in many plant species is regulated by environmental factors such as night length in photoperiodic flowering and temperature in vernalization (Khokhar, 2014). Vernalization is the artificial exposure of plants to low temperatures in order to stimulate flowering or to enhance seed production. Optimum vernalization temperatures are associated with the highest seed yields in onions. The duration and intensity of cold needed to meet vernalization requirements vary widely among crops and even among varieties of the same species. Cold temperatures between 5oC and 13oC for 20 to 120 days were optimum for flower induction in most cultivars. Research was conducted for three years at Melkassa to determine the optimum vernalization period for flower stalk development, and the results indicate that six weeks of storage produced a significantly higher number of flower stalks per plant (Lemma and Shimelis, 2003). So, in the absence of easily bolting cultivars, the application of vernalization treatments could therefore be given to non-easily bolting cultivars at a temperature of 5–10 oC for about 6 weeks and planted during the cool season (September to January) in order to develop flower stalks and set seed under Melkassa and similar conditions (Lemma and Shimels ,2003). Brewster, J.L. (1987) also reported that the relative rate of vernalization increases with increasing bulb weight. As a result, inflorescence primordia in larger bulbs is in a more advanced stage than that of small bulbs at the time of planting, resulting in earlier inflorescence emergence (early bolting) and floret opening. Plants from bulbs stored at 7oC for the first half (3 months) and 2oC for the last half (3 months) of the storage period had a higher seed yield than those from bulbs stored continuously at 7oC or at 2oC for the first half followed by 7oC for the last half (Demille and Vest, 1976).

2.5.3. Pollination

Protandry in onions promotes outcrossing, and therefore onion is a cross-pollinated crop. Honey bees are the principal pollinating agents, although blowflies can also be used as alternative or supplementary pollinators in commercial seed production (Currah 1981; Peters 1990). Bad weather, especially high rainfall and humidity during the flowering period, can reduce onion seed yield by decreasing the activity of bees, with a consequent reduction in their pollination efficiency.

2.5.4. Method of Onion Seed Production

2.5.4.1. Bulb-to-seed method

Onion bulbs are produced, harvested, stored, and then replanted in order to produce seeds using the bulb-to-seed method of seed production. Before planting bulbs for seed production producer remove or reject off-type, infected, or otherwise undesired bulbs. Up to 7–12 flower stalks and 250–1000 flowers are produced in the Melkassa conduction bulb to seed method (Lemma and Shimelis, 2003). In order to initiate flowering, mother bulbs are vernalized by chilly temperatures for one to two months while being stored. Planting depth for the vernalized bulbs is between 10 and 15 cm. Large, well-developed umbels are produced by it, which is advantageous for high-quality seed production. However, the formation of seeds takes ten to twelve months (4 months for bulb production).

2.5.4.2. Seed-to-seed method

The seed-to-seed approach involves planting seeds that are carried over into the field as bulbs over the winter and bloom in the spring. While the bulb-to-seed approach can be utilized every two years to expedite the seed production effort, the seed-to-seed method of seed production lost all of the previous benefits. Although the total expenses are lower than with the bulb-to-seed approach and seed production takes 7-8 months, pest management needs to be closely monitored. The bulb-to seed approach is recommended for high seed yield, variety maintenance, and ease of care (Lemma and Shimelis, 2003). Research experience at the Melkasa Research Center showed that the bulb-to-seed method of seed production has a greater advantage over the seed-to-seed method of seed production. Several flower stalks of 2 to 17 were formed per bulb with 250 to 1000 florets per stalk. It produced large and well-developed umbels that are favorable for high-quality seed production. It takes 5 to 6 months for stalk t and seed development. But from the seed-to-seed method of production employed, it was obtained only 2 to 3 flower stalks per plant with very low seed yield (Lemma and Shimelis, 2003). A comparative study was conducted in Bangladesh to produce seeds in the bulb-to-seed method and the seed-to-seed method during 1987/88 by Amzud and Jamiul (1993). Accordingly, 616.7 kg/ha^{-1} of seeds were produced from the bulb to seed method as compared to 34.9 kg/ha^{-1} of seeds from the seed to seed method of production.

2.5.5. Mother Bulb Size (cm)

2.5.5.1. Effect of mother bulb size on bolting

Bolting is the development of a seed flower stalk, important for onion seed production but not for bulb production. Different sizes of onion mother bulb showed significant effect on growth and quality of theseeds (Ashenafi et al., 2016). Bulb size is one of the most important production factors that need to be taken into consideration for bolting to occur. Sensitive to low temperature increase with bulb size. Small sets (12.5 mm diameter) showed little or no bolting, and the percentage of bolting increased with increasing set-size following a linear relationship (Khokhar, (2009). (Ashenafi et al.,(2017) reported that days to 50% bolting were significantly earlier (21 days) for bulbs with 3 to 4 cm size, while it was significantly late (27 days) for bulbs with 6.1 to 7 cm size. Least number of days to complete flower stalk bolting on small bulb sizes as compared to the largest ones. The increase in number of days to 50% bolting with the increase in bulb size might be due to the presence of stored food inside the larger bulbs that contributed to the vegetative growth of plants through which bolting was delayed. In contrast According to Mohammad et al. (2015) biggest bulb size (12 gm) gave larger numbers of umbels per plant than the umbels grown from the medium (8 gm) and small (4 gm) ones. Small bulbs gave the lowest umbel diameter with smaller inflorescences than the medium and large ones. The author indicated as bulb size increased, the number of flower stalks per bulb increased, as did seed production per plant and per hectare.

2.5.5.2. Effect of mother Bulb size on 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; Maria ,(2016).

Several researches indicated that the initiation of inflorescences is favoured by large set or bulb size. From an experiment conducted in Samara Ashenafi (2017) Days to 50% flowering were lowest (61 days) for bulbs with 3 to 4 cm sizes, while it was highest (75 days) for 6.1 to 7 cm sizes. Ahmed et al. (2020) also reported that Bulb size had highly significant effect on plant height and the largest bulb produced significantly the tallest plant (49.83 cm) than those of smallest bulb (43.92 cm) up to 60 day after planting. The higher number of flowers per umbel (301.33) was found from large size bulb and the lower no. of flowers per umbel (212.17) was recorded in small size of bulb. A larger mother bulb has a larger food supply and water content than the smaller bulbs which responsible for development of vigorous plants and production of higher seed yields. (Khokhar., 2014). Teshome et al. (2014), found that 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.

2.5.5.3. Effect of Bulb size on Yield and Yield Component of Onion Seed

Bulb size has an impact on the development of flower stalks and the start of inflorescences, both of which affect the quantity of seed stalks and flowering, which in turn affects seed yields. The effects of bulb size on onion seed production have been reported by Ashenafi et al. (2017). Mother bulb size for onion seed production is different across the country due to variation in agro ecology. Ahmed et al. (2020) conducted a field experiment at Bangladesh Mymensingh during the period from October 2018 to March 2019 to examine the effects of different bulb sizes, viz., large size bulb (15±1 g), medium size bulb (10±1 g), and small size bulb (7±1 g), on seed production of two onion varieties (Taherpuri and KalashNari). The result showed that significant effect in both varieties on plant height, leaf number; number of umbels per plot, umbel diameter, and seed yield per hectare were obtained from the KalashNagari variety with a big bulb of 15±1 g. In September 2011–2012, Mollah et al. (2015) studied the impact of bulb size on the quantity and quality of true onion seeds produced in Mymensingh, Bangladesh. The results showed that the number of seeds/umbel, plant height, number of stalks/plant, and yield per hectare were all significantly affected by bulb size. Particularly, large bulb (20g) had the most seed results (20 g). From a statistical standpoint, there was little difference between medium (15 g) and large (20 g).

Bulb size determines the vigor of the reproductive phase and the number of reproductive shoot initials. This is directly related to the number of seed stalks and subsequent seed yield. Lemma and Shimeles (2003) were tested for seed production potential in Melkassa for three seasons in order to determine the optimum size for high seed yield and quality. Maximum seed yield was obtained from bulb size excess of 4.1 cm diameter and produced vigorous umbels of above 5 cm diameter, a large number of flower stalks (as many as 360/100 m^2 kg/m^2), and almost double the seed yield (695 kg/100 m^2) of bulbs of small size.

Ud-Deen (2008) carried out an experiment to investigate the impact of planting time and mother bulb size on onion growth, bulb yield, and seed yield. Different-sized onion bulbs (20 g, 15 g, and 10 g) were planted on October 30, October 15, and November 30. Higher bulb and seed yields were attained by planting early and using 20 g of mother bulb weight. The maximum bulb (17.52 t/ha) and seed (0.4 t/ha^{-1}) yields were obtained from treatment combinations involving a big mother bulb (20 g) and planting on October 30. Higher seed output (920 to 995 kg/ha^{-1}) was also reported by Ashenafi et al. (2016) with large bulb size grows spaced 20 and 25 cm apart.

Teshome et al. (2014) reported significant effects of bulb size and planting time on seed yield per hectare. According to them, the highest seed yield (1.155 t/ha^{-1}) was obtained from large bulb sizes planted on 25 October, followed by medium bulb sizes planted on the same date (0.983 t/ha^{-1}), while the least (0.075 t/ha^{-1}) was obtained from small bulb sizes planted on 15 November. The most important components for onion seed production are umbel size, flower stalk height, number of flower stalks per plant, and flower stalk diameter, which are closely related with the size of mother bulb and cultivars. Maria Tesfaye (2016) Reported bulb size had significant differences in the number of flowering stalks and their length, number of umbels per plant, number of seeded umbels, and seed weight per umbel, 1000-seed weight, and seed yield per hectare, especially with yield positively correlated. Mohammad et al. (2015) indicated that the flower stalk length (40.02 cm and 67.73 cm) was found in medium size bulb whereas small size bulb produced the lowest (34.15 cm and 67.14 cm) flower stalk length at 65 and 85 DAP, respectively.

According to Asaduzzaman et al. (2012) large-sized bulbs produced the highest flower stalk, whereas small-sized bulbs produced the shortest floral stalk. Also, he mentioned that the weight of the bulb (15±2 g) had a much higher number of flowering stalks per plant (3.63), whereas the small weight of the bulb (5±2 g) had the lowest number (2.45). Larger bulbs are believed to have larger food reserves and to be responsible for more flowers per umbel and more blooming stalks per plant. Flower stalk number was directly related to bulb size within each line. Khokhar (2014) also reported bulbs with 6.9 cm diameter produced a higher number of flower stalks compared to those with 4.8 cm. Mother bulb size had a significant effect on the number of umbels per plant. According to Mohammad et al. (2015), the number of umbels per plant was found to increase with the increase in bulb size. The highest number of umbels per plant, 3.22, was produced from the large mother bulb size, which was followed by the medium bulb size (3.03), and the lowest number of umbels per plant, 1.58, was produced in the small bulb size.

The number of flower stalks per plant varied from 1 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, 2013). Salari et al., (2022) and Tesfaye et al., (2018) reported that number of leaves per plant, number of flower stalks per plant, flower stalk diameter, flower stalk height, number of seeds per umbel, 1000-seed weight and seed yield were recorded for large bulbs. The most significant indicator of seed results was umbel diameter, which was highly impacted by base flower stalk diameter. Large bulbs have a significant effect on the umbel's diameter. The plants with the largest bulbs generated the largest umbel diameter, which was followed by the medium-sized bulbs. 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 bulbs of different sizes (20 g, 15 g, and 10 g) that 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^{-1}) and seed (0.4 t/ha^{-1}) yield. According to Peters (1990), larger bulbs produced more seeds per plant and made it simpler to select bulbs with an appropriate shape and resistance to bolting than did smaller ones. While it makes sense to utilize enormous bulbs for seed production, medium-sized bulbs are actually used since larger bulbs have a shorter shelf life. Larger-budded cultivars yielded more seeds and wider inflorescences. The wide variance in the number of umbels per plant and the quantity of fruitful florets per umbel among the cultivars was the reason for the variation in yield (Prats et al., 2007). According to Sidhu et al. (2016) and Taminaw, (2021), certain onion cultivars have larger seed yields since they have more seed stalks per plant. Teshome et al. (2014) reported significant effects of bulb size and planting time on seed yield per hectare. According to them, the highest seed yield (1.155 t/ha^{-1}) was obtained from large bulb sizes planted on 25 October, followed by medium bulb sizes planted on the same date (0.983 t/ha^{-1}), while the least (0.075 t/ha^{-1}) was obtained from small bulb sizes planted on 15 November.

2.5.6. Fertilizer

2.5.6.1. Nitrogen

2.5.6.1.1. Effect of Nitrogen on Yield and Yield Component of Onion Seed

Onion being among nitrogen feeder vegetables, its productivity depends on the amount of fertilizer rates, and if not applied properly, considerable yield losses are apparent. Nitrogen plays an important role for the optimum yield of onions and is found to be essential to increasing the bulb size and yield. Due to their shallow and unbranched root structure, onions are the most susceptible agricultural plants in terms of nutrient extract, especially the immobile nutrient; as a result, they require fertilizer application and usually respond well to it (Rizk et al., 2013).

Based on the amount of each nutrient necessary for a healthy plant, plant nutrients can be broadly categorized into two groups: macronutrients, which are sometimes needed in large quantities, and micronutrients, which can be required in only trace amounts. Wiedenhoeft, Alex C. (2006). Macronutrients like nitrogen and phosphorus are important for onion yield components, yield, and quality. Nitrogen, being the most often growth-limiting nutrient, is found to be an essential constituent of metabolically active compounds such as amino acids, proteins, co-enzymes, and some non-pertinacious ones (Demis,2021). Nitrogen also plays a critical role in the structure of chlorophyll, the primary light-harvesting compound of photosynthesis. Nitrogen deficiency is commonly exposed to chlorosis. In the case of nitrogen-deficient chlorosis, the effects are first seen in the more mature leaves and tissues. The plant will preferentially export nitrogen to actively growing tissues, leaving the more mature parts of the plant to show signs of deficiency first. Nitrogen deficiency affects not only the leaves of the plant but all living cells that have high nitrogen demands for amino and nucleic acids, reducing overall productivity and plant vigor.

Demis et al. (2019) indicated that the shortest days to 50% bolting and days to 50% flowering were recorded from the combination of N at a rate of 0 kg ha^{-1} with P at a rate of 70 kg and 105 kg P2O5 ha-^{1}, and the combination of N at a rate of 150 kg ha-1 with P without delayed days to bolting and days to flowering, respectively. He also stated that the highest yield (1858.82 kg/ha^{-1}) was obtained from the combined application of N at 100 kg N ha^{-1} and P at 70 kg P_2O_5ha^{-1}.Increasing application rates of N fertilizer increased the seed yield per plant, and seed yield increased linearly from 830 to 1100 kg/ha^{-1} with increasing N at the rate of 0 to 150 kg/ha^{-1} of N. N rate at 50 or 100 kg/ha^{-1} with P at 50 kg/ha^{-1} increased seed yield from 1840 kg/ha^{-1} to 2260 kg/ha^{-1} compared to the control treatment. However high N plants tended to become more vegetative and often bulbed rather than bolted. According to Ahmed (2012), bolting, onion seed production, and seed quality are impacted by fertilizers N, P, and K. According to Abdissa et al. (2011), N fertilizer dramatically decreased onion bolting, and he stated that when compared to the control, the ratio of bolting percentage per plot decreased by roughly 11 and 22% in response to fertilization with 69 and 92 kg N ha^{-1}, respectively.

Umbel diameter was the most important index for seed yield, and this character was influenced strongly by base flower stalk diameter. (Prats et al.,1996). Amare et al. (2020) conducted research on the effect of plant spacing and NP fertilizer levels on growth, seed yield, and quality of onion (*Allium cepa* L.) at Shewa Robit, Northern Ethiopia, to determine optimum plant spacing and NP fertilizer for high yield and quality seed production of onion. The highest umbel diameter (6.366 cm) was obtained when plants were grown at 20 × 30 × 50 cm double row spacing, which was followed by 10 x 20 x 40 cm double row spacing. Accordingly, the larger umbel diameter (6.267 cm) was obtained with the NP application at rates of 115 P_2O_5 and114 N kg ha$^{-1,}$ which, were followed by 143.6 P_2O_5 and 142.5 N kg ha^{-1}. The diameter of the umbel was small when plants were grown control. The author also stated that the highest number of seeds per umbel (914.6) was recorded from plants that received 115 P_2O_5 and 114 N kg ha^{-1}, followed by 143.6 P_2O_5 and 142.5 N kg ha^{-1}.

2.5.7. Effect of Bulb size and Nitrogen Fertilizer rate on Seed Yield Quality of Onion Seed

Kiros et al. 2018 reported days to bolting, days to 50% flowering, days to maturity, flower stalk diameter, numbers of umbels per plant, umbel diameter, and number of seeds per umbel and seed weight per umbel were significantly affected by the main effect of NP fertilizer rates. Basnet et al. (2015) reported the interaction effect of nitrogen and bulb size on onion seed production. The bigger bulb size in association with a high nitrogen level up to 160 kg N/ha^{-1} increased plant height, number of tillers, leaves, scapes, umbels, and flowers per plant. He also stated the highest yield (300.2 kg/ha^{-1}) and lowest (200.1 kg/ha^{-1}) were obtained from the bigger bulb size and 160 kg ha^{-1} N. Khinthwe (2014) tested the effect of five N rates (0, 50, 100, 150, and 200 kg ha^{-1}) and four P_2O_5 rates (0, 25, 50, and 75 kg ha^{-1}) on the onion seed yield. The main effects of N and P and their interaction on number of umbels per bulb, seed weight per umbel, and seed yield were significant, but there were no significant effects on plant stand or 1000 seed weight.

According to Debashis et al. (2017), larger-sized bulbs produced the largest plant height, number of leaves, and number of flower stalks per plant. Smaller bulbs, on the other hand, had the opposite effect. This could be due to the fact that larger bulbs have a greater capacity for internal food storage than smaller ones, which encourages strong vegetative development characterized by increased plant height, leaf count, and number of flower stalks per plant. At ShewaRobit in Northern Ethiopia, Amare et al. (2020) studied the effects of plant spacing and NP fertilizer levels on onion (Allium cepa L.) growth, seed yield, and quality. The author found 114 kg ha-^{1} of nitrogen was ideal fertilizer rates for producing high-yield and high-quality onion seeds in the area.

Adequate N fertilization is essential for good quality and yield of onion production. According to Tamrat (2006), N fertilization at 138 kg ha^{-1} showed a highly significant effect on flower stalk diameter, number of umbels per plant, number and weight of seeds per umbel, and seed yield per plant. Teshome et al. (2021) reported that the large bulb size gave the maximum seed yield (2.8 tha^{-1}) of onion, decreasing the seed yield (1.2 tha^{-1}) from the small bulb size planted. Demis et al. (2017) also found that the combinations of higher rates of both N (100 and 150 kg ha^{-1}) and P (70 and 105 kg P_2O_5 ha^{-1}) resulted in better seed yield per umbel, seed yield per plant, and seed yield per hectare, and the lowest mean seed yield was recorded from control treatments. The above finding indicated that seed yield of onion is determined by mother bulb size and fertilizer. Several workers have reported a greater seed yield in large bulbs and attribute this to a larger amount of available assimilates in large bulbs. It was observed the big bulbs gave a larger number of seed stalks than the medium and small ones, Khalid (2014). Demis et al. (2019) indicated that the combination of 100 kg N with 70 kg P_2O_5ha^{-1}, brought about 57.72% increments in seed yield per hectare over the control. In general, the seed yield showed an increasing trend with the combinations of higher N rates with higher P_2O_5, and he concluded that as N rates increased, onion seed maturity delayed. Debashis et al. (2017) also reported that N at 175 kg ha^{-1} recorded the significantly highest seed yield per plant. According to Hossain et al. (2011), application of different doses of macronutrients increased the number of umbels per plot, number of seeds per umbel, weight of seeds per umbel and seed yield.

The maximum number of seeds per umbel, weight of seed, seed yield per plant, and seed yield per hectare were found from 114 N and 42 P kg ha^{-1} treatments, and the minimum number of seeds per umbel, weight of seed, seed yield per plant, and seed yield per hectare were found from 57 N and 21 P kg ha^{-1} treatments, respectively (RR). According to Abas et al. (2015), the result indicated that N fertilization significantly increased the length of leaves, number of leaves, length of flowering stalk, and number of flowers per umbel. The highest records for the four growth parameters were obtained at 90 kg N ha^{-1}fertilization.

3. MATERIALS AND METHODS

3.1. Site Location and Description

The experiment was conducted in November 2016 under irrigation conditions at the Axum Agricultural Research Center (AARC) Tselimeilla horticulture division research site, which is 5 km to the east of Axum town. Geographically, the experimental site is located at Hatsebo in La’elay Maichew district, Central Zone of Tigray. It is located at the latitude of 13^0 15’ N and longitude of 38034’ E with an altitude of 2042

m. a. s. l. in the semi-arid tropical belt of Ethiopia with the “Weinadega” agro climatic zone (Figure 1). The rainy season is monomodal, concentrated in one season from July to September, with an average rain fall of 700–800 mm. The mean minimum and maximum temperatures range from 8.70°C to 13.20°C and 24.40°C to 31.40°C, respectively. The soil type is classified as vertisol, with a characteristic feature of clay soil type.

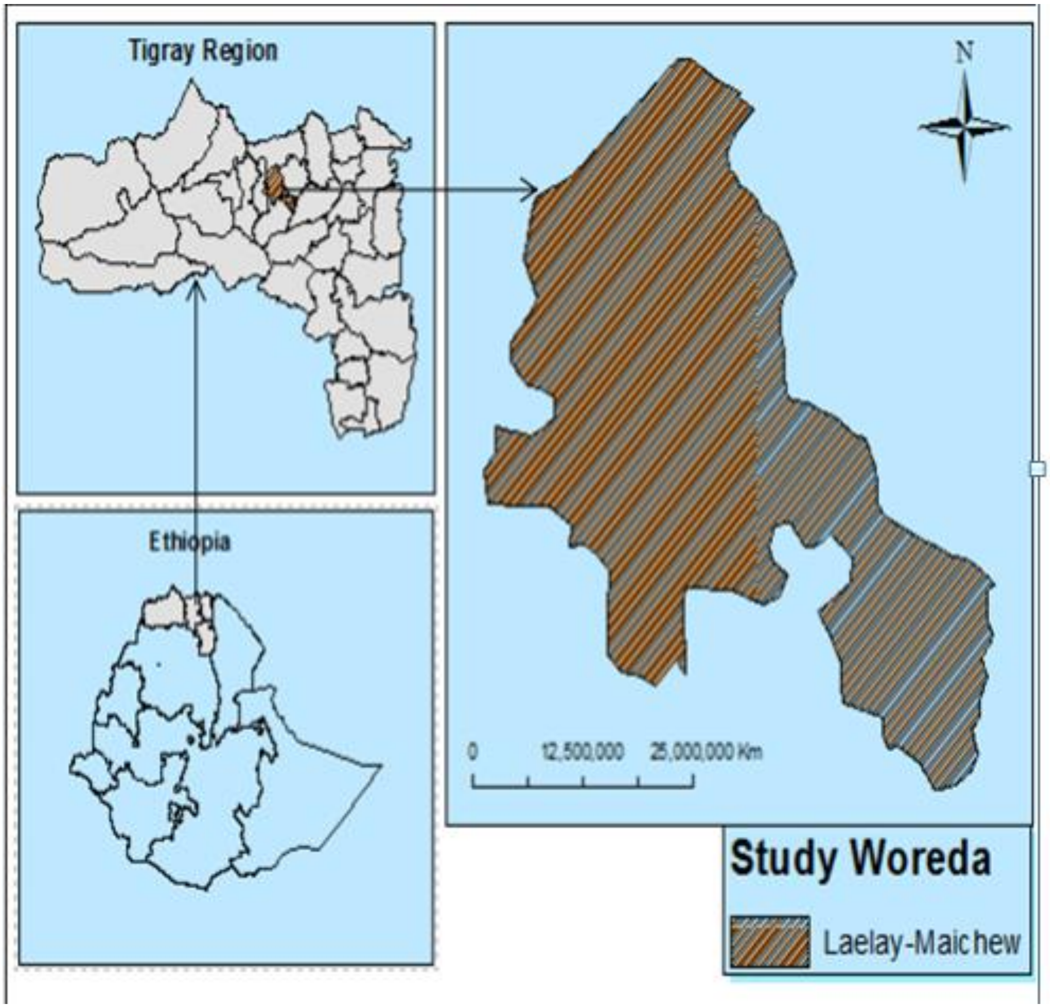

Figure 1: Map of the Study Area

3.2. Experimental Design and Treatments

The experiment was laid out in a 3x5 factorial using a randomized complete block design (RCBD) with three replications. The treatment consisted of three different mother bulb sizes (diameter): small (3-4 cm), medium (4.1-5 cm), and large (5.1-6 cm) and five levels of nitrogen (0, 23, 46, 69, and 92 N kg/ha^{-1}). A plot size of 3.2 x 2.2 m^2 (7.04 m^2) was used for each experimental unit, and the total area of the experiment was 12.6m x 47 m and the net plot size was 6.04m^2. Each treatment was assigned to the plots randomly. Mother Bulb of Onion was planted in a double row with spacing of 50, 30, and 20 cm between water furrows, rows on the bed, and plants in the rows, respectively (Olani and Fikre, 2010). The blocks were separated by 1.5 m in width, whereas the space between each plot within a block was 1 m. Each experimental plot had eight single rows (ridges), which consisted of 88 plants per plot. During data collection, the middle rows were considered for recording all data, excluding the two border rows.

3.3. Experimental Materials and Procedures

The Bombay Red' onion variety was used for the study. Bombay red varieties can grow at an altitude of 700–2000 m.a.s.l. and give 30–40 bulb yields tons/ha^{-1}). It takes 90–120 maturity days for seed production by the bulb-to-seed method, and the seed yield potential of the cultivar is 1.3–2 tons ha^{-1} (Lemma & Shimeles, 2003; EIAR, 2012; Kiros et al., 2018). The variety has a light red bulb skin color, a dark green leaf color, a flat globe bulb shape, and a reddish white bulb flesh color. The planting material, or mother bulb of the onion, was obtained from the farmer research group (FRG) in Tahtay Maychew Woreda May Atsmi Tabya. Bombay Red is one of the most commonly and widely used varieties in the Tigray region. The sources of the N and P fertilizers were urea (46% N) and Triple Super Phosphate (TSP) (46% P_2O_5) respectively. The triple superphosphate (TSP) was obtained from the Mekelle Soil Research Center. The experimental area was cleared and plowed four times with an oxen plow. The field was then divided into three blocks, each with fifteen plots. To break dormancy, bulbs of a normal color free of pests, diseases, and mechanical damage were chosen, and they were stored or placed on wooden shelves for four weeks at room temperature until all of the bulbs sprouted from mid-October to mid-November. For final planting bulbs, these free from insect, disease, and mechanical injuries were measured from 3 to 6 cm (small to large) size by using a digital caliper. Prior to planting, the mother bulbs were sliced off one-fourth top part to facilitate germination and easy and quick sprouting of growing buds. Hand planting of bulbs was done on the furrow's ridges according to the suggested spacing. Triple superphosphate (46% P_2O_5) was applied as sources of P at the rate of 92 kg P_2O_5 for all plots uniformly. All TSP fertilizer was applied at planting as a single application (92 kg $P_2O_5ha^{-1}$) and incorporated to the soil on the prepared ridges in bands. Urea was side dressed in two splits of equal amounts after 2 weeks of seedling emergence and 6 weeks after planting. Soil samples were taken before planting in order to assess the soil's nutritional condition. In order to promote bulb germination, the plots were irrigated in accordance with the area's suggestion, which was three days after planting, and the irrigation interval was increased to seven days after full flowering and then to ten days after that, followed by ten to fifteen days after maturity. All significant agronomic procedures, such as weeding, cultivating, and ridging, was carried out in accordance with recommendations from the time the onion bulb was planted until it was harvested. The seed was harvested when 50% of the seed color changed to black.

3.4. Data Collection

Data was collected at different growth stages from the middle three center double rows of plants, which were selected randomly in each plot, regarding several aspects of growth, yield component, and seed yield.

On the other hand, information regarding the phenology of the plants was obtained from the entire experimental plot.

Crop Phenology and Growth Parameters

Days to 50% bolting: This was recorded as the number of days from date of planting up to when 50% of the plants in a plot produced flower stalk.

Days to 50% flowering: number of days from planting the mother bulb of onion to the day on which 50 percent of the flower stalks in each plot produced flowers.

Days to 50 % seed maturity: numbers of days from date of planting mother bulb of onion up to when 50 %of the plants in each plot matured or ready for harvest (when the seed color changed to black or the capsule turned brown and started splitting.

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

Flower stalk length (cm): Refers to the mean height of ten randomly selected plants from central row from each plot. Height was measured from the end of the sheath or from the base of flower stalk part to the umbel.

Flower stalk diameter (mm): The diameter of flower stalk was measured at the widest part of stalk (scrape) by using caliper and taken from ten randomly selected plants from the central double rows at flowering stage from each plot and the average was calculated.

Yield and Yield Components

Number of flower stalks per plant: Number of flower stalk per plant was taken from ten randomly selected plants in each experimental plot at first harvest and the average calculated and recorded as the number of flower stalks per plant.

Umbel diameter (mm): This refers to the mean umbel diameter of the 10 randomly selected plants in each plot. The diameter was measured using a caliper two times measuring in two opposite direction (north-south and east to west).

Number of seeds per umbel: refers to total number of seed with in umbels were taken from the ten sample plants in each plot, dried, threshed and then counted and divided by 10 obtain number of seeds per umbel.

Seed weight per umbel (g): Ten randomly sample umbels was harvested, dried, threshed to determine seeds weight per umbel and the average weight of seed per umbel was calculated by dividing the total weight of seeds to number of the umbels.

Thousand seed weight (g): The weight of random sample of thousand seeds in grams was recorded as thousand seeds weight from each treatment.

Seed yield per plant (g/plant); the average weight of seed was taken in grams from the ten sample plant of three double rows in each experimental units.

Seed yield (g/plot): The total seed yield was obtained from the net plot size.

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

3.4.1. Soil data before planting of the onion bulb

Tigray Agricultural Research Institute, Mekelle soil Research center, Mekelle Soil Laboratory processed the soil sample that was taken from the experimental site. Before planting, soil samples were taken at random from the whole experimental field at a depth of (30) cm using an augur, and one kg of composite samples was created. The zigzag approach was used to take the soil. Based on the composite sample, a few specific soil chemical parameters were determined. In order to analyze the composite soil sample's physical and chemical characteristics, it was allowed to air dry before being crushed using a wooden pestle and mortar and put through a 2 mm sieve. From the sample provided, the following parameters were determined in the laboratory: total nitrogen, available phosphorus, potassium, organic matter, soil pH, cation exchange capacity (CEC), and soil texture. Soil pH was measured in 1:2.5 soil-to-water ratios using an electrode pH meter. The Walkley and Black method was used to determine the soil's organic carbon content (Walkley and Black, 1934). However, available phosphorus was calculated using the industry standard method (Olsen et al., 1954). The Kjeldahl method was used to estimate the total nitrogen (Jackson, 1958). The results of the soil analysis were used as input in determining the applied amount of nitrogen fertilizer and to recognize the appropriateness of the selected site for onion seed production during the experimental period.

3.4.2. Soil data

Surface soil samples (0-30 cm) was collected and the collected soil samples data was analyzed for these physico-chemical properties

3.5. Data Analysis

Using R statistical software, all data collected for the current study were subjected to analysis of variance (ANOVA) in accordance with a procedure suitable for a randomized complete block design (Gomez and Gomez, 1984). Least significant differences at 5% level of probability was used to compare the treatment mean differences at the $p<0.05$ probability level when the analysis of variance indicated the presence of significant treatment differences. Correlation analysis was computed to generate information about the association of yield and other parameters. The association between the traits was also analyzed using Pearson's Correlation coefficient (r) method. The ranges of Correlation coefficient (r) values are between ± 0.8 and ±1.0 (high correlation), between ± 0.6 and ± 0.79 (moderately high), and between ± 0.4 and ± 0.59 (moderate), and weak correlation is between ± 0.2 and ± 0.39were considered.

3.6. Economic Analysis (Partial Budget Analysis)

For combined seed yield data, partial budget analysis was used to analyze the economics of fertilizer application and mother bulb. The economic viability of fertilizer application is ultimately determined by the crop's possible reaction to the additional fertilizer, the cost of mother bulbs, and fertilizers applied during planting (CIMMYT, 1988). The market price of onion seed was taken during harvest, and the current prices of urea and mother bulb were collected at planting time in order to assess the overall costs. The following is the economic analysis, which was based on the formula created by CIMMYT in 1988:

Gross average bulb yield (kg ha^{-1}) (AvY): was an average yield of each treatment.

Adjusted yield (AjY): was the average yield adjusted downward by a 10% to clarify the difference between farmers' production and experimental yield.

. **AjY = AvY- (AvY-0.1).**

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. **GFB = AjY*field/farm gate price**

Total cost: was the cost of urea and mother bulb and cost of transportation of bulb used for the experiment. Their prices were based on 2023 price during planting. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, crop protection and harvesting were assumed to remain the same or were insignificant among treatments.

Net benefit (NB): was calculated by subtracting the total costs from gross field benefits for each treatment.

NB = GFB – total cost

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in cost which was the measure of increasing in return by increasing input.

4. RESULTS AND DISCUSSION

4.1. Result on Selected Soil Physico-chemical Properties Prior to Planting

The results of the soil analysis are presented in Table 2.The total nitrogen content of soil was 0.052%, which is low according to Goronski et al. (2010). The N content of soil between 0.15-0.25 percent is medium and greater than 0.25 percent is high. Available phosphorus of soil was categorized within medium (23 ppm), which was based on the ranges rated by Olsen et al. (1954).The soil of the experimental site, TselimEilla, had a 45-meq/100-g soilcation exchange capacity (CEC), which is high according to

Egel et al. (2014). Cation exchange capacity is a measure of the soil's ability to hold exchangeable cations such as hydrogen (H), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), and aluminum (Al). Cation exchange capacity is measured in terms of milli equivalents (meq) per 100 grams of soil (Hazelton and Murphy, 2007). The experimental site had 0.364 dSm/m electron conductivity and a pH of 8.6 close to alkaline. According to Nikus and Mulugeta (2010), the pH range of 6 to 8 is suitable for the formation of onion seeds. Therefore, the soil's pH was adequate (conformable) for the production of onion seeds. The experimental soil was characterized by 0.450% organic carbon that was characterized as low. According to Tekalign (1991), soils having more than 3% organic carbon may not need any side dressing of nitrogen fertilizer. The soil sample analysis showed that the experimental site was deficient in total nitrogen and organic carbon; hence, it requires the application of nitrogen to boost onion seed production.

Table 1: Physicochemical Properties of the experimental soil

Soil properties	Values	Soil Status	Reference
Soil chemical property			
PH(1:2.5H_2O)	8.600	Alkaline	Nikus and Mulugeta (2010)
Organic Carbon (%)	0.450	Low	Tekalign (1991)
Total Nitrogen (%)	0.052	Low	Goronski et al. (2010
Available Phosphorous(mg/kg)	23.00	Medium	Olsen et al. (1954)
CEC(cmol (+)kg	45.00	High	Egel et al. (2014)
Electrical Conductivity(ds/m)	0.364	Non-Sline	Hazelton and Murphy, (2007)
Soil physical property			
Sand (%)	12.000		
Silt (%)	18.000		
Clay (%)	70.000		
Textural Class	Clay		Hazelton and Murphy (2007)

N-nitrogen: P-phosphorous: K-potassium: EC-electron conductivity: CEC-Cation exchange capacity

4.2. Growth and Phonological Parameters

Days to 50%bolting

The result from the analysis of variance indicates that there was no significant interaction effect between bulb size and nitrogen fertilizer rate, while the main effect of bulb size and nitrogen fertilizer rate significantly (P<0.01) influenced days to 50% bolting (Table 3).When the diameter of the mother bulb increased from 3-4 cm to 4.1-5 cm, days to bolting decreased. Onion planted with large bulb size (5.1-6 cm) required a minimum number of days (52.80) to bolt, and it was found to be statistically similar (54.06 days) with the onion planted with medium mother bulb size. On the other hand, smaller mother bulb sizes (3–4 cm) took the maximum number of days to bolt. The plant bolted early (about 4 days earlier) when it was grown large mother with bulb size (5.1-6 cm) compared to the small size (3-4 cm).

With increasing the rate of nitrogen from 0 to 23, kg ha^{-1}a significantly decrease 50% days to boltingwas observed. However, increasing the rate of nitrogen from 23 to 46 and 69kg ha^{-1} did not show significant difference in days to 50% bolting and also was not statistically significant difference between the between the rates. Thus, days to 50% bolting were significantly bolted early (53 days) onion plant treated with nitrogen at the rate of 69 kg ha^{-1} while it was significantly late (56.77) without nitrogen application or from the control.

Decreasing bolting percentage in response to large mother bulb size might be due to rate of vernalization increase with increasing mother bulb size or bulb weight. As a result, inflorescence primordia in larger bulbs is in a more advanced stage than that of small bulbs at the time of planting, resulting in earlier inflorescence emergence (early bolting) and floret opening (Khokhar, 2014). In agreement with the present result, Ami et al. (2013) found that large bulb sizes are more affected by vernalization and ensure early bolting and flowering, resulting in the production of an early seed crop. Small bulb sizes showed little or no bolting, and the percentage of bolting increased with increasing bulb sizes following a linear relationship. Badawi et al., (2010) reported that increasing chilling durations increased bolting in onions, consequently increasing seed yield. Other studies have also shown that inflorescence initiation is favored by large set/bulb size (Khokhar, (2009).

Decreasing in days to 50% bolting with the addition of a higher amount of nitrogen could be due to the highest level of nitrogen, probably due to the availability of more nutrients, which helped in maximum vegetative, bolting, flowering, and seed yield onion plant. Hassan (2011) also reported that both bolting and doubling were increased at the higher N level. Jilani (2004) and Hassan and Ayoub (1978) also reported providing nitrogen to onions increased the percentage of bolters and the amount of blooms. It can be assumed that when nitrogen fertilizer is applied, higher phosphorous uptake from the soil improves by the plant.

In contrast to this finding, Marschner (2015) reported a high bolting percentage in plants treated with low levels of nitrogen fertilizer application. Bolting incidence decreased steadily with an increase in nitrogen fertilization rate, according to Diaz-Perez et al. (2003), who also proposed that inadequate nitrogen fertilizer application enhanced bolting. This could be because the element influences the lowering of sugar content in the leaves during the early ripening stage and the blockage of the translocation of digested products, which both affect the availability of carbohydrates during the key period of the reproductive phase.

Table 2: Main effect of bulb size and nitrogen fertilizer levels on Days to 50% bolting

Treatment	Days to 50% bolting
Bulb size (cm)	
3-4	56.60a
4.1-5	54.06b
5.1-6	52.80b
LSD (5%)	1.34
N level (kg ha-1)	
0	56.77a
23	54.22bc
46	53.66bc
69	53.00c
92	54.77b
LSD (5%)	**1.73**
CV	**3.29**

Means represented with the same letter(s) in each treatment are not significantly difference from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = Coefficient of variation in percent.

Days to 50% flowering:

The analysis of variance revealed that the main effects of nitrogen fertilizer rate and mother bulb size were highly significantly ($P < 0.05$) influenced in Days to 50% flowering **(**Table 4).The interaction effect of nitrogen fertilizer application level and bulb size also significantly influenced Days to 50% flowering.

With increasing bulb size, days to 50% flowering of onion seed significantly decrease across different rates of nitrogen application level. Thus, large bulb size (5.1-6 cm) and 69 N levels (kg ha^{-1}) were the treatment combination at which earlier for days to 50% flowering at about 72.67 dayswas observed. On the other hand, the highest days to flowering were obtained from the combination of smaller bulb sizes (3–4 cm) without nitrogen fertilizer application (control). However, the combination of small mother bulb size (3-4 cm) and 23 kg N ha^{-1} was statistically non-significant difference with small bulb size and without nitrogen. Treatment combination 69 kg N ha^{-1} and 5.1-6cm bulb size was earlier in days to 50% flowering by 5.67 days than small bulb size with nil nitrogen fertilizer application. Therefore, earlier in days to 50% flowering of onion seed were recorded from the treatment combination of large bulb size (5.1-6 cm) and nitrogen rate of 69 kg N ha^{-1}.

A minimum day to flowering of onion was obtained in treatment combination of larger mother bulb size and higher nitrogen fertilizer level. This may be due to large bulb size contributed to the plants by giving enough amounts of reserved food and more affected by vernalization than small bulb size and nitrogen fertilizer enhanced in days to 50% flowering due to metabolic and physiological activities that increase respiration and growth of the plant (Kiros et al., 2018). The present finding is in agreement with the results of Khokhar (2008), who indicated that the time it required for flowers to open shortened as bulb size increased, with large bulb sizes initiating inflorescence earlier than small sets. (Abas et al., - 2016) showed that the longest time to flowering was recorded from the control treatment, and the shortest time was obtained by the application of 90 kg N ha^{-1}. This could be because applying nitrogen accelerated vegetative growth and development, which in turn brought about early flowering. Demis et al. (2019) also stated that the days to flowering were moderately increased when the levels of N increased to 50-100 kg ha^{-1}. According to Teshome et al. (2014), large bulbs planted on 25 October flower early (69 days), while the longest days to attain 50% flowering were recorded from small bulb sizes planted on 15 November (82.67 days). Demis (2021) reported that early flowering umbels benefit from maximum assimilate partitioning and better dry matter accumulation for seed set.

In contrast to this finding Gebeyehu, (2018) noted that higher nitrogen has physiological features in plants that enlarge the plumpness and succulence of vegetation, frequently bulbinstead of bolting.It was due to the high nitrogen that can prolong vegetative growth stage, leading to delayed 50% flowering (khin, 2014).

Table 3: Interaction effect of bulb size and nitrogen fertilizer levels on Days to 50%flowering

Bulb size (cm)	**N level (kg ha-1)**	**Days to 50% flowering**			
	0	23	46	69	92

3-4	78.33a	77.66a	74.00cde	73.66cde	74.66bcd
4.1-5	76.00b	75.00bc	74.33cd	73.33de	73.66cde
5.1-6	74.66bcd	74.00cde	74.00cde	72.66e	73.66cde
LSD (5%)	**1.48**				
CV	**1.18**				

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent.

Days to 50% maturity:

The analysis of variance showed that a day to 50% maturities was highly significantly ($P < 0.01$) influenced by bulb size, nitrogen fertilizer, and the interaction of the two (Table 5). With increasing mother bulb size, days to 50% maturity were decreasing significantly across the increasing rate of the different nitrogen fertilizer level. Onion plant grown without nitrogen with small mother bulb sizes (3-4 cm) and 23 kg ha^{-1} with small bulb size (3-4 cm) has led to significantly delayed maturity time (130 days). On the other hand, the shortest (123.66 days) in days to 50% maturity were attained in the treatment combination of large bulb size (5.1-6 cm) and 69 of N kg ha^{-1}.

The earlier days to maturity depicted from large bulb size and 69 ka ha^{-1}nitrogen fertilizer level treatments might be due to large bulbs contributed to the plants by providing enough quantity of reserved food and a good supply of nitrogen, which stimulates root growth and development as well as the uptake of other nutrients. In agreement with the result of this study, Khokhar (2014) reported that the larger the mother bulb weight, the shorter the period of low temperature (9˚C) exposure required for flower bud formation and maturity of onion seed. Khokhar (2008) stated that large sets initiated inflorescence sooner than small sets and time to floret opening decreased with increasing set size. Larger bulbs have earlier inflorescence emergence (early bolting), floret opening, and maturity because their inflorescences are in a more advanced stage when they are planted than those of small bulbs. These results were in harmony with those reported by Brewster (1987) and Khokhar (2014) stated that relative rate of vernalization rises and maturity times were lower as mother bulb size increases.

In contrast to the present result reported by Abdissa et al. (2011), maturity of onion plants, was delayed in response to increasing nitrogen application. Ashenafi et al. (2017) also reported that the lowest (106 days) to 50% maturity was achieved at 3 - 4 cm bulb sizes. The delay in maturity due to N fertilizer application could be possibly due to the fact that this element affects the supply of carbohydrate during the critical period of the reproductive phase through its effect on the reduction of sugar concentration in the leaves during the early ripening stage and inhibition of the translocation of assimilated products (Marschner, 2015). Sørensen and Grevsen (2001) reported that ample nitrogen supply could result in excessive vegetative growth and delayed maturity of onions.

Table 4: Interaction effect of mother bulb size and nitrogen fertilizer levels on Days to 50%maturity

Bulb size (cm)	**N level (kg ha-1)**	**Days to 50% Maturity**			
	0	23	46	69	92
3-4	130.00ab	130.00ab	129.00abc	129.33ab	130.33a
4.1-5	129.66ab	129.00abc	126.66ef	128.66abcd	127.33cde
5.1-6	127.33cde	127.00def	125.33fg	123.66g	128.33bcde
LSD (5%)	**1.73**				
CV	**0.80**				

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent.

Plant height (cm)

The result from the analysis of variance indicated that plant height was highly significantly ($p<0.05$) affected by the main effect of bulb size and nitrogen fertilizer rate. However, the two factors did not interact to influence plant height (Table 6). The tallest plant height (76.07 cm) was recorded from the large bulb size (5.1-6 cm), and the shortest plant height (72.05 cm) was recorded from small mother bulb size (3-4 cm,).However, statistically, there were no significant differences with the medium mother bulb size. Similarly, increasing nitrogen fertilizer levels from nil to 23 kg ha^{-1} increased plant height significantly. Increasing the rate of nitrogen further from 23 to 46 and 69 kg ha^{-1} also increased the height of onion plants significantly, whereas the increase in nitrogen level further from 69 kg ha^{-1} to 92 kg ha^{-1} was decreasing plant height and statistically did not show a significant difference as further increase in nitrogen rate from 69 to 92 kg ha^{-1}. Application of 69 kg ha^{-1} nitrogen fertilizer rate had recorded the maximum plant height (81.4 cm), and the lowest 61.08 was recorded from the control. Thus, the height of onions received with nitrogen at the rate of 69 kg ha^{-1} exceeded the height of onion plants treated without N by about 25%.

Increasing plant height at the large bulb size may be due to the large bulb size having enough reserve food to support growth and development of the plant, which may lead to maximum plant height and a significantly taller plant as compared to the medium and small bulb size. This result agrees with the finding of Ahmed et al. (2021), who reported that bulb size had a highly significant effect on plant height and leaves per plant. UdDeen (2008) founded that maximum plant height (61.07 cm) and numbers of leaves per plant (18.23) were produced by the large mother bulb, which was significantly higher than the medium and small-sized bulbs. He also stated that the large mother bulb showed better performance in all yield components compared to that of the medium and small mother bulbs. Corroborating the results of this study, the largest bulb produced the tallest plant, followed by the medium and smallest bulb (Khan et al., 2005; Basnet et al., 2018).

The increase in plant height with the addition of higher nitrogen fertilizer level could be attributed to more availability of the nutrient which enhances protein synthesis which lead to increased accumulation of carbohydrates and this in turn, may have resulted in increased plant growth such as leaf number and leaf length (Rizk, 2012;Tekle,2019). This result is consistent with the findings of Morsy et al. (2012):Nasreen et al. (2007) and Al-Fraihat (2009) who reported that onion plant height significantly increased as nitrogen fertilizer rates increased. The positive effect of N on plant growth may be attributed to its role in the synthesis of chlorophyll, enzymes, carbohydrates, and proteins, essential for vegetative growth Havlin et al(2010).According to Tagayeet al. (2022), the higher N fertilization was related to the production of new shoots and vigorous vegetative growth.UdDeen et al (2019) indicated that increase in onion plant height at increased application of N could be attributed to its involvement as building blocks in the synthesis of amino acids, as they link together and form proteins and make up metabolic processes required for plant growth. Ali et al.(2007) reported that the highest plant height was recorded from plot received higher dose of nitrogen. Sidhu et al.(2016) discovered that the plant heights of other onion cultivars ranged from 76 to 93 cm. This increase in height caused by applied nitrogen fertilizer may be influenced by the major role that nitrogen plays in the higher rates of vegetative growth and stem elongation that occur when plants receive high doses of nitrogen fertilizer (Marschner, 2015; Gupta and Sharma, 2010).

Flower stalk length (cm)

Flower stalk height was highly significantly ($p<0.001$) influenced by nitrogen fertilizer rate. The main effect of bulb size and interaction of the two factors, however, didn’t affect flower stalk height **(**Table 6).The highest flower stalk (69.6cm) were recorded for nitrogen application at the rate of 69 kg ha^{-1}and this was statistically similar with plant treated by 92 kg N ha^{-1}(69.25cm).On the other hand lowest flower stalk height (52.86cm) was obtained from the control treatments. Application of N at the rate of 69 kg ha^{-1} brought by about 24% increments in flower stalk height as compared to the control.

This increase in flower stalk height caused by applied N may have resulted from a primary factor of N leading to higher rates of stem elongation and vegetative development when plants are fertilized with higher nitrogen(Demis (2019; Gupta and Sharma, 2000). The taller flower stalk height might have provided more photo assimilation to the plant, causing the weight of each seed to be greater than the weight of seed from plants with short scapes.

The result was in accordance with Tamrat (2006), Debashis et al. (2017), and Damarany et al. (2016), who stated that the highest flower stalk height was achieved by the highest nitrogen rate, which was significantly higher than the medium and small nitrogen doses. Whereas the minimum effect of nitrogen fertilization on flower stalks per plant was found from lower nitrogen doses. A similar trend was found by Abas et al. (2016): the longest flower stalk (81.6 cm) was observed from the plant that received 90 kg N ha-^{1}, while the onion plant without fertilization or the control gave the shortest flower stalk. Abusarra (2006) reported that an increase in nitrogen level resulted in increased stalk height in small and midsize bulbs compared to that large size bulb. Sidhu et al. (2016) noticed that the length of the flower stalks varied among onion cultivars and ranged from 76 to 93 cm. This increase in flower stalk height caused by the application of N may be partially attributed to the major role of N in driving higher rates of vegetative growth and stem elongation when high doses of nitrogen fertilizers are applied.

Table 5: Main effect of bulb size and nitrogen fertilizer levels on plant height and flower stalk length of seed

Treatment	Plant height (cm)	Flower stalk length (cm)
Bulb Size(cm)		
3-4	72.05b	64.62a
4.1-5	73.46b	62.90a
5.1-6	76.07a	64.62a
LSD (5%)	2.20	2.27
Nitrogen fertilizer (kg N ha^{-1})		
0	61.08d	52.86d
23	70.07c	60.55c
46	75.90b	64.21b
69	81.41a	69.60a
92	80.84a	69.25a
LSD (5%)	**2.84**	**2.88**
CV	**3.99**	**4.71**

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent,

Flower stalk diameter (mm)

Flower stalk diameter was highly and significantly influenced (P<0.001) by the main effect of nitrogen fertilizer application level. The main effect of bulb size and interaction of the two factors, however, didn’t affect flower stalk diameter (Table 7).

The result of the analysis of variance indicated that flower stalk diameter increased significantly with increasing the rate of nitrogen application. Numerically, the largest flower stalk diameter (13.45 mm) was recorded from the plant treated with nitrogen at a rate of 92 kg ha^{-1}, which was statistically similar to 69 kg ha^{-1} of nitrogen. Whereas, the lowest flower stalk diameter (10.34 mm) was recorded from the control treatment or without fertilizer application. 46 and 23 kg ha^{-1} had no significant difference among them on flower stalk diameter. The flower stalk diameter increased by 23.1% when nitrogen fertilizer was applied at a rate of 92 kg ha^{-1}, compared to the control treatment (10.34 mm).

The reason for the maximum flower stalk diameter at higher nitrogen fertilizer due to the highest level of nitrogen was probably due to the availability of more nutrients, which helped in maximum vegetative growth of the plant. Those results are in harmony with the finding of Ahmed and Abdalla (2006), which conducted an experiment over the course of two seasons and revealed that the application of nitrogen had a significant effect on plant height, flower stalk thickness, and seed yield. Kiros et al. (2018) also stated that the highest flower stalk diameter (15.03 mm) was recorded from 75% recommended dose of NP fertilizers. Tamrat (2006) also found that the highest flower stalk diameter was from 138 kg N ha^{-1}, followed by 92 kg N ha^{-1}. Amare et al., 2020), also found the highest flower stalk diameter (1.56 cm) was recorded from NP fertilizers 115 P_2O_5 and 114 N kg ha^{-1} and the lowest 13.34 mm.

Table 6: Main effect of mother bulb size and nitrogen fertilizer levels on flower stalk diameter (mm)

Treatment	**Flower stalk diameter (mm)**
Bulb size (cm)	
3-4	12.09a
4.1-5	12.04a
5.1-6	11.84a
LSD (5%)	0.57
Nitrogen fertilizer (kg N ha-1)	
0	10.34c
23	11.68b
46	11.72b
69	12.77a
92	13.45a
LSD (5%)	1.84
CV	6.37

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent.

4.3. Yield and Yield Components

4.3.1. Number of flower stalks per plant

The number of flower stalks per plant was significantly ($P<0.001$) affected by the main effect of nitrogen fertilizer and mother bulb size (Table 8). However, the interaction effect of nitrogen fertilizer level and mother bulb size did not affect the number of flower stalks.

In response to increasing mother bulb size, the number of flower stalks also increased significantly. Numerically, the highest number of flower stalks (8.82) was obtained from the large mother bulb size (5.1–6 cm), but there was no statistically significant difference from those medium sizes of mother bulb (4.1-5 cm) with the number of flower stalks (8.30). On the other hand, onions planted with small mother bulbs had a minimum number of flower stalks per plant. Onion planted with large mother bulb size (5.1–6 cm) brought about 11.6% increments in the number of flower stalks per plant over smell mother bulb size. The highest numbers of flower stalks in the large mother bulb could be due to the superiority of the large mother bulb, which may contain higher food reserves and be responsible for the higher number of flower stalks per plant. Similar kinds of findings were also reported by Maria and Roman (2013), who reported that large bulbs produced greater numbers of seed stalks than small ones, and small bulbs produced seed stalks with smaller inflorescences than medium and large ones. Corroborative results regarding the influence of bulb size were also reported by Ahmed et al. (2021), who obtained the highest number of umbels per plot from the large bulb, and the lowest was found in the small bulb. Flower stalk number was one of the most important components for onion seed production, which is closely related to the size of the mother bulb (Demis, 2019). The number of flower stalks per plant varied from 1 to 15 per plant and the terminal number of 50-200 flowers produced per umbel on "Adama Red" depending on the number of shoots axis (Lemma, 2003). It is generally accepted that large bulbs produce more flower stalks and give higher seed yields. In response to increasing nitrogen fertilizer level from nil to 23 kg $^{ha-1}$, the number of flower stalks increased significantly. However, increasing the rate of nitrogen rate from 23 kg N ha^{-1} to 46 kg ha^{-1} statistically did not change the number of flower stalks per plant. The highest numbers of flower stalks per plant were recorded in a plot that received 69 kg N ha^{-1} and 92 kg N ha^{-1} (8.38, 8.22, respectively). On the other hand, the lowest number of flower stalks per plant was recorded from control treatments. The increase in the number of flower stalks per plant at 69 kg ha^{-1} of nitrogen fertilizer-applied plots compared with unfertilized plots was about 11.58%. The increase in the number of flower stalks per plant at the higher rate of nitrogen might be due to the higher dose of nitrogen; the vegetative growth of the onion plant was increased, which helped to increase the number of flower stalks per plant. The present findings are in line with those of Rashid and Singh (2000), Tamrat (2006), Debashis et al. (2017), and Demis et al. (2019), who reported that an increase in nitrogen fertilization increases the number of umbels and flower stalks per plant. Basnet et al, (2015), also found increase in nitrogen fertilizer rate from 0 kg

$^{ha-1}$ to 160 kg ha^{-1}, increase number of flower stalk per plant from 1.38 to 2.90 at 105 days after planting. Ali et al. (2007) also found a higher number of tillers per plant from the plant receiving the higher nitrogen rates. Due to the higher dose of nitrogen, the vegetative growth of the onion plant was increased, which helped to increase the number of tillers per plant. Hossain et al. (2011) reported that the maximum numbers of flower stalks were produced from the highest rate of nitrogen.

Table 7: Main effect of mother bulb size and nitrogen fertilizer levels on number of flower stalk per plant

(Treatment	**Number of flower stalk**
Bulb size (cm)	
3-4	6.81b
4.1-5	8.30a
5.1-6	8.82a
LSD (5%)	0.68
Nitrogen fertilizer (kg N ha^{-1})	
0	7.41b
23	7.70ab
46	8.17ab
69	8.38a
92	8.22ab
LSD (5%)	**0.91**
CV	**11.88**

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent,

4.3.2. Umbel diameter, (mm)

Nitrogen application level very highly significantly ($p<0.001$) affected umbel diameter, but bulb size, interaction of bulb size and nitrogen fertilizer level didn't affect umbel diameter (Table 9). The diameter of the umbel in response to different mother bulb sizes in onion was not much variable, ranging from 38.99 to 39.63 mm. In contrast to this finding, Mohammad et al. (2015) noted onions planted with different mother bulb sizes had significant variation in umbel diameter due to bulb size. The highest umbel diameter (9.27 cm) was found in the medium-size bulb, which was followed by the large and small-size bulbs (8.93 cm and 8.66 cm). It could be due to a higher supply of food materials to the umbel by the larger bulb size. In response to increasing nitrogen fertilizer level, umbel diameter increased significantly. Hence, the maximum (43.89mm) umbel diameter was recorded from the 92 kg ha^{-1} application level of nitrogen, followed by 69 kg ha^{-1} (41.84mm) and kg ha^{-1}(40.12mm) nitrogen fertilizer levels. The lowest umbel diameter (33.36 mm) was obtained from control or without fertilization. When the application of nitrogen increased to 92 kg Nha^{-1}, umbel diameter increased by 23.99% as compared to the control. The increase in umbel diameter of onion at 92 kg Nha^{-1} might be due to the onion plant receiving higher nitrogen fertilizer and significantly increased number of leaves, length of flower stalk, and number of flowers per umbel. Application of nitrogen increased the vegetative growth, produced good-quality foliage, and promoted carbohydrate synthesis, thereby producing larger umbel diameters).The highest records of umbel diameter were obtained by 90 kgha^{-1} N fertilization (Abas et al., 2015). This result is in line with that of Amare et al., 2020, who reported that the largest umbel diameter (6.26 cm) was recorded from the plant treated with the rate of 115 kg P_2O_5 and 114 kg N ha^{-1}. Kiros et al. (2018) also reported that the highest umbel diameter was recorded from the plant that received NP fertilizer at the rate of 75% recommended dose of NP. The largest umbel diameter was obtained from the treatments that received a higher nitrogen rate, (-Demis et al. (-2017). Umbel diameter was the most important index for seed yield, and this character was influenced strongly by base flower stalk diameter (Demis, 2021).

Table 8:Main effect of mother bulb size and nitrogen fertilizer levels on umbel diameter (mm) of onion plant

Treatment	**Umbel Diameter (mm)**
Bulb size (cm)	
3-4	39.53a
4.1-5	39.63a
5.1-6	38.99a
LSD (5%)	**1.43**
Nitrogen fertilizer (kg N ha-1)	
0	33.36b
23	37.70c
46	40.12b
69	41.84b
92	43.89a
LSD(5%)	**1.84**
CV	**4.86**

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent,

4.3.3. Number of seeds per umbel

The analysis of variance revealed that the main effects of nitrogen application rate and mother bulb size highly significantly ($P < 0.001$) influenced the number of seeds per umbel of the onion plants. The interaction effect of nitrogen application and mother bulb size also significantly influenced the number of seeds per umbel (Table 10).

With increasing mother bulb size, the number of seeds per umbel of onion significantly increased across the different rates of nitrogen application. The number of seeds per umbel ranged from 550.00 to 233.60 with an average of 368.10. Teshomeet al. (2014) reported that average 515.3 to 256.6 seeds per umbel.

Therefore, the current study's result supports previous findings. Numerically, the highest number of seeds per umbel (550) was obtained from the combination of medium bulbs (4.1–5) with 92 kg ha^{-1} of nitrogen application rate, but it was on par with the one obtained from the combination of large bulbs (5.1-6 cm) with 69 and 92 kg ha^{-1}of nitrogen level (528.8,530), respectively. On the other hand, the lowest number of seeds per umbel was recorded from the combination of small mother bulb size and without application of nitrogen fertilizer. When comparing the number of seeds per umbel of onion, the treatment combination 92 kg N ha^{-1} and medium bulb size (4.1–5 cm) increased the number of seeds per umbel of onion by 56.6% as compared to the small mother bulb without nitrogen application.

Higher numbers of seeds per umbel were recorded almost in large mother bulb sizes, and a higher nitrogen fertilizer rate may be associated with a possible reason for nitrogen's influence on the amount of seeds per umbel could be that it has a significant role in reducing floral abortion on the umbel. (-Demis et al., (2017). In fact, a plant growing in large mother bulb sizes produced the highest number of seeds per umbel, which may also have been caused by the increased amount of assimilates that are available in large bulbs (Khokhar, 2009). The present finding is in agreement with the result of Ahmed et al. 2021) who indicated that the number of effective seeds per umbel increased with the increase in bulb size. (Ahmed et al., 2021) found that large bulb sizes produced the highest number of fruits, while small bulbs produced the lowest number of fruits. Manna, (2016) observed that the greatest number of seeded florets per umbel was produced by large mother bulb sizes, and the lowest values for these parameters were recorded in small bulb sizes. Hossain et al. (2011) also stated that different levels of macronutrients significantly increased the number of seeds per umbel and maximum numbers of seeds per umbel (555.20) were found from the N114 kg/ha^{-1} treatment, and the minimum number of seeds per umbel (494.00) was found from the N57 kg/ha treatment. Debashis et al. (2017) proved that nitrogen at 175 kg $^{\text{ha-1}}$ recorded the substantially greatest (744.34) number of seeds per umbel, which is consistent with these results. Ali et al. (2007) also stated that higher nitrogen doses produced the highest number of fruit sets per umbel.

4.3.4. Seed weight per umbel (g)

The analysis of variance indicated that the interaction of different bulb sizes and nitrogen fertilizer levels significantly ($p<0.05$) influenced seed weight per umbel (Table 10). The maximum weight of seed per umbel (2.32 g) was obtained from the treatment combination of large bulb size and 69 kg N ha^{-1}.Small mother bulb sizes (3-4 cm) and 0, 23, and 46 kg N ha^{-1} exhibited the lowest seed weight per umbel at 0.92, 1.00, and 1.00, respectively. But these had no statistically significant difference with large mother bulb size (5.1-6 cm) and nil nitrogen fertilization. Large mother bulb size (5.1-6 cm) shows superiority over small mother bulb size (3-4 cm) Seed weight per umbel by 37.8% at the 69 kg N ha^{-1} fertilizer application. The majority of mother bulb size interactions produced seed weight per umbel in a straight line in response to higher nitrogen fertilizer rates. However, some interactions of the mother bulb size with N fertilizer rates did not show a defined trend in producing seed weight per umbel at the increased rates of nitrogen fertilizer application.

This indicated that the weight of the seeds per umbel increased simultaneously with the increased application of nitrogen fertilizer, and small mother bulbs gave comparatively lower seed weight per umbel. Nitrogen's role in the accumulation of carbohydrates and other metabolites may be the cause of the high seed weight per umbel when treated with high N fertilizers. According to Abas et al. (2016) moderately heavy seeds should be produced whenever nitrogen is introduced. Similar to the current study, the highest seed weight per umbel (2.74 g) was obtained from the large-sized bulb, and the lowest seed yield (1.85 g) was found from the small-sized bulb (Ahmed et al., 2021). Amare et al. 2020), who recorded the heights of seed weight per umbel from the plants that received N at a rate of 150 kg ha^{-1}, which was statistically similar to 100 kg N ha^{-1}. The plants produced with no nitrogen fertilizer application had the lowest seed weight per umbel. Similar results were also reported by Hossain et al. (2011) and Kiros et al. (2018). Ali et al. (2008), who reported that seed weight per umbel was significantly increased by NP fertilizer 115 N kg ha^{-1} and 114 P_2O_5 kg ha^{-1} and 150 N and 80 P_2O_5 kg ha^{-1} applications, respectively.

4.3.5. Thousand Seed weight (g)

The analysis of variance indicated that the main effect of nitrogen and bulb size significantly affected the thousand seed weight. Moreover, the two factors interacted to influence this parameter significantly ($P < 0.01$) (Table 10).

Increasing size of mother bulb significantly increased thousand seed weight across the increasing rate of the nitrogen fertilizer. Thus, the maximum thousand seed weight, (3.86 g), was recorded from the treatment combination of large mother bulb size (5.1-6 cm) and 69 kg N kg ha^{-1}. On the other hand, the minimum thousand seed weights (2.3 g) were recorded from small bulb sizes and without fertilization. Thousand seed weight of onion plants grown with large mother bulb size (5.1-6 cm) and nitrogen rate of 69 kg N ha^{-1} exceeded thousand seed weight onion grown at smaller mother bulb size (3-4 cm) with without nitrogen by about 40.4%. This result indicated that plants that did not receive fertilizer and small bulb sizes produced the lowest 1000 seed weight. In general, seed weight increased along with increases in N rates. This might be due to the fact that nitrogen is a basic component of starch and carbohydrate in the seeds of plants; these components actively function as the building blocks of the seed components, which increase the onion seed's weight(Amare et al., (-2020). The results of this study are in accord with those of Dudhat et al. (2010), who reported that a treatment combination of 5-6 cm mother bulb size and 100-50-50 NPK produced the maximum thousand seed weight, but statistically it was on par with a bulb size of 7-8 cm. Corroborating the results of this study, UdDeen (2008) also showed that thousand seed weight increased in response to increasing mother bulb size. Ozer (2003) and Ozden (2009) also showed that heavier seeds were produced through the application of higher rate of nitrogen. Likewise, Gethe et al. (2006) and Amare et al. (2020) also reported similar results.

Table 9: Interaction effect of mother bulb size and nitrogen fertilizer levels on number of seed per umbel, seed weight per umbel and thousand seed weight

Bulb size (cm)	**N level (kg ha^{-1})**	**Parameter**		
		Number of seeds per umbel	**Seed weight per umbel (g)**	**Thousand seed weight(g)**
3-4	0	238.66e	0.92h	2.3g
	23	253.33e	1.00h	2.5fg
	46	275.20e	1.00h	2.86e
	69	298.53de	1.33efg	2.66ef
	92	407.33c	1.43def	2.93de
4.1-5	0	246.66c	1.10gh	2.46fg
	23	296.00de	1.22fgh	2.83e
	46	374.26c	1.48cdef	2.90e
	69	494.83ab	1.81b	3.23c
	92	550.00a	1.71bcd	3.56b
5.1-6	0	233.60e	0.98h	2.93de
	23	368.80cd	1.55bcde	3.20cd
	46	425.50bc	1.75bc	3.23c
	69	528.80a	2.32a	3.86a
	92	530.00a	1.79b	3.63ab
LSD (5%)		**74.06**	**0.30**	**0.27**
CV		**12.03**	**12.59**	**5.45**

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent.

4.3.6. Seed yield per plant (g/plant)

The analysis of variance revealed that the main effects of nitrogen application level and mother bulb size significantly ($P < 0.05$) influenced seed yield per plant. The interaction effect of nitrogen application rate and bulb size also significantly influenced the seed yield per plant (Table 11).

The average seed yield per plant ranged from 17.2 g to 8.13, with an average of 12.7 g. The highest seed yield per plant (17.20 g) was obtained from the large mother bulbs treated with 69 kg ha^{-1} of nitrogen fertilizer level, followed by medium mother bulbs treated with 92 kg ha^{-1} of nitrogen (16.66 g). The lowest seed yield per plant (8.13 g) was obtained from medium mother bulb size without nitrogen. But it was not statistically significant different from those small mother bulb sizes (3-4 cm) and nil nitrogen fertilizer (9.13 g).The variation in seed yield per plant might be due to differences in the number of flower stalks per plant, the number of umbels per plant, number of seeds per umbel and seed weight per umbel. This result agrees with the finding of Teshome et al. (2014), who reported higher onion seed yields from plants grown from bigger bulbs. Cuocolo and Berbieri (2006) stated that increasing application rates of N fertilizer increased the seed yield per plant. Debashis et al. (2017) indicated that nitrogen at the rate of 175 kg ha^{-1} recorded the significantly highest seed yield per plant. Ahmad et al. (2021) reported the large mother bulb weight produced vigorous plants and higher yield. However, the seed yield produced from medium bulbs was statistically similar with large bulbs. Asaduzzaman et al. (2012) also reported that seed yield per plant was significantly varied due to different bulb sizes. Consistent with the results of this study, Basnet et al. (2015) also reported that the number of flowers per plant and seed yield per plant were significantly highest at the higher rate of nitrogen and medium bulb size. Ogawa in 2011 also found that seed yield per plant was positively and significantly correlated with the number of seed stalks per plant and seed yield per umbel. According to Rabinowitch and Brewster (2010), yield of seed per plant increased as the nitrogen in the nutrient solution increased where seed stalks were produced.

Table 10**:** Interaction effect of mother bulb size and nitrogen fertilizer levels on seed yield of onion per plant (g)

Bulb size (cm)		Nitrogen level(g)			
	0	23	46	69	92
3-4	9.13f	12.25de	12.16de	12.06de	12.66de

4.1-5	8.13f	14.03cd	12.90cde	16.23ab	16.66ab
5.1-6	11.83e	15.00bc	13.76cde	17.20a	16.26ab
LSD (5%)	2.10				
CV	9.44				

Means represented with the same letter(s) in each treatment are not significantly different from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = coefficient of variation in percent,

4.3.7. Seed yield per plot (g)

The main effect of mother bulb size and that of nitrogen fertilizer level, as well as the interaction effect of the two factors, highly significantly ($P < 0.01$) influenced seed yield per plot (Table 12).

Seed yield per plot increased with mother bulb size and almost at all application rate of nitrogen. Hence, the maximum seed yield of 1197.91 g per plot was achieved from the combination of large mother bulb size (5.1-6 cm) and an application rate of 69 kg N ha^{-1}. On the other hand, the least seed yield of 601.03 g/plot was recorded from small bulb size (3-4 cm) and without nitrogen. Thus, the highest seed yield per plot obtained in response to the application of 69 kg N ha^{-1} at large mother bulb size (5.1-6 cm) exceeded the seed yield per plot grown from control and small mother bulb size (3-4 cm) by 49.482%.

The increase in onion seed yield per plot in response to the application of 69 kg ha^{-1} nitrogen with the large mother bulb size (5.1-6 cm) may be due to the larger mother bulb having a larger food supply and water content than the other sizes, which enabled the development of vigorous plants and the production of higher seed yields, and due to the increased seed yield of individual plants in response to the increased level of nitrogen. Basnet et al. (2015) reported that the highest seed yield per plot was produced at 160 kg N/ha^{-1} and a bulb size of >3 cm. The results of the present study are in agreement with the finding of Gebeyehu, (2018), who reported that higher seed yield in onion was due to the higher number of seed stalks per plant and to a wider umbel diameter which were influenced by application of N. The highest onion seed yield per plot was recorded at application of higher nitrogen. Similarly, Dudhat et al. (2010) reported that the highest seed yield of onion seed per plot was obtained with large bulb sizes.

Table 11: Interaction effect of mother bulb size and nitrogen fertilizer levels on seed yield of onion per plot (g)

Bulb size (cm)	N level (kg ha^{-1})	Seed yield (g/plot)			
	0	23	46	69	92
3-4	629.42g	844.35ef	902.42def	798.20f	967.66cde
4.1-5	601.03g	988.88bcde	903.01def	1074.12abc	1129.20ab
5.1-6	1019.95bcd	1055.69abcd	1073.23abc	1197.91a	1096.96abc
LSD (5%)	**153.74**				

CV	**9.65**

Means represented with the same letter(s) in each treatment are not significantly difference from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = Coefficient of variation in percent.

4.3.8. Seed Yield Per hectare (kg/ha^{-1})

The analysis of variance revealed that interaction effect of nitrogen application rate and mother bulb size significantly ($P < 0.1$) influenced seed yield per hectare (Table 13). Large Mother bulb size and nearly every nitrogen application rate resulted in an increase in seed output per hectare. As a result, a big mother bulb size (5.1-6 cm) and an application rate of 69 kg N ha^{-1} combined to produce the highest seed production of 1983.25 kg ha^{-1} per hectare. On the other hand, medium bulb size (4.1–5 cm) and nitrogen-free plants produced the lowest seed output (995.06 kg ha^{-1}). As a result, the greatest seed production per plot at big mother bulb size (5.1-6 cm) in response to 69 kg N ha^{-1} was 49.482% higher than the seed yield per plot developed from control and small mother bulb size (4.1-5 cm).

It is possible that the larger mother bulb size (5.1-6 cm) had a larger food supply and water content than the other sizes, which allowed for the development of vigorous plants and the production of higher seed yields. It is also possible that the increased seed yield of individual plants in response to the increased level of nitrogen is what caused the increase in onion seed yield per plot in response to the application of 69 kg ha^{-1} nitrogen. The current study's findings concur with those of Gebeyehu (2018), who found that increased onion seed yield was caused by more seed stalks per plant and a broader umbel diameter, both of which were impacted by N application. The largest yield of onion seeds per plot was observed when more nitrogen was applied. In a similar vein, Dudhat et al. (2010) found that large bulb diameters produced the maximum onion seed yield per plot. Increase seed yield per hectare in large mother bulb sizes, maybe due to the relative large amount of food reserves stored in large bulbs, which enhanced the production of healthy and vigorously growing plants with a large number of seed heads and consequently increased seed yield per hectare as compared to small mother bulb sizes.

This result agrees with the finding of Ud Deen (2008) and Teshome et al. (2014), who founded that onion seed yield per hectare could be affected by the mother bulb size and planting time, and the highest seed yield was obtained from large mother bulbs, while the lowest seed yield was obtained from small mother bulb size. Corroborating the results of this study, Basnet et al. (2015) also showed that seed yield per hectare was significantly varied due to different bulb sizes. Ashenafi et al. (2017) also reported that different bulb sizes had a significant effect on seed yield per plant, which increased with an increase in bulb size and planting time. The bulb weight had a significant effect on seed yield, and the larger bulbs (126–175 g) produced the highest yield (820.83 kg ha^{-1}) (Ahmad et al., 2021). The increase in seed yield per hectare with the addition of a higher nitrogen fertilizer level might be due to the role of nitrogen in the buildup of carbohydrate and different metabolites in seed formation and development (Amare et al., 2020).Results of this study were in conformity with that conducted by Abas et al. (2016), who reported that seed output increased with increasing fertilizer dose up to 90 kg N ha^{-1}; there was no noticeable increase in seed yield with higher fertilizer dose. (Cuocolo and Berbieri, 2006), also stated that N fertilizer levels from 0 to 150 kg $^{ha-1}$ in 30 kg ha-1 increments showed that seed yield increased linearly from 830 to 1100 kg ha^{-1} with increasing N. Fraihat (2009) and Tekle (2019) also reported that onion seed yield per heater significantly increased as nitrogen fertilizer rates increased. Demsi et al. (2017) also founded better seed yield per umbel, seed yield per plant, and seed yield per hectare from the combination of higher rates of both nitrogen and phosphorus. The findings regarding the impact of bulb size on seed output per hectare are largely consistent with the findings of research conducted by Anisuzzaman et al. (2009) and Manna (2016), which also showed that larger bulbs produced higher seed yield per hectare.

Table 12: Interaction effect of mother bulb size and nitrogen fertilizer levels on seed yield of onion per hectare (kg/ha^{-1})

Bulb size (cm)	N level (kg ha^{-1})	Seed yield (g/plot)			
	0	23	46	69	92
3-4	1042.03e	1398.43cde	1494.03bcd	1321.50de	1602.03abcd
4.1-5	995.06e	1637.20abcd	1025.9333e	1778.300abc	1869.500ab
5.1-6	1656.38abcd	1747.80abcd	1776.83abc	1983.25a	1816.13abc
LSD (5%)	440.80				
CV	17.08				

Means represented with the same letter(s) in each treatment are not significantly difference from each other. LSD (5%) = least significant difference at P<0.05, CV (%) = Coefficient of variation in percent.

4.4. Correlation Analysis

Correlation coefficient values were calculated for the different response variables, which help to explain how the yield components and growth characteristics affect the seed yield of onions. Hence, it was observed that seed yield of onion per hectare was highly significantly positive, moderately high positive, moderate positive, and had a weak correlation with plant height (r = 0.47**).Flower stalk length (r=0.41**), flower stalk diameter (r=0.28*), number of flower stalk per plant (r=0.37, umbel diameter (r=0.34*), number of seed per umbel (r=0.55**), seed weight per umbel (r=0.53**), thousand seed weight (r=0.68**), seed yield per plant (r=0.67**), and seed yield per plot (r=0.83**). This illustrates that the use of different combinations of mother bulb size and nitrogen fertilizer levels for increasing vegetative growth and yield component results in the indirect selection of mother bulb size and nitrogen level combinations for increasing onion seed yield. However, seed yield per hectare yield showed moderately negative and weak negative correlation with days to 50% bolting (r = -0.43**), days to 50% flowering (-0.47**), and days to 50% maturity (r = -0.37*). The negative correlation between onion seed yield and days to 50% bolting, 50% flowering, and days to 50% maturity indicated that a decrease in bolting, flowering, and maturity result in an increase in seed yield of onion per hectare. The result was in line with Demis et al. (2019). Similar findings have also been reported by Khokhar (2009 earlier in bolting; flowering and maturity of onions produce more flower stalks and give a higher seed yield. Seed yield per plant was highly significantly positive, moderately high positive, moderate positive, and correlated with plant height (0.69**), flower stalk length (0.60**), flower stalk diameter (0.52**), flower stalk diameter (0.61**), number of seeds per umbel (0.75**), seed weight per umbel (0.72**), and thousand seed weight (0.81**) and seed yield per plot (0.84**). Similarly, moderate positive and weak correlation were observed for numbers of flower stalk per plant with plant height (r = 0.39), flower stalk length (0.30), flower stalk diameter (00), umbel diameter (0.19), number of seeds per umbel (0.49*), seed weight per umbel (0.49*), and thousand seed weights (0.61**), and seed yield per plot (0.58*), but moderately negative and weak negative correlation with days to 50% bolting (-0.57), days to 50% flowering (-0.40), and days to 50% maturity (-0.33) and no correlation with flower stalk diameter (0.00).Ogawa in 2011 showed that seed yield per plant was positively and significantly correlated with the number of seed stalks per plant and seed yield per umbel. Umbel diameter was strong and highly significantly positive, with a moderately positive correlation with plant height (85), flower stalk length (83**), flower stalk diameter (0.85**), number of seeds per umbel (0.65**), seed weight per umbel (0.55**), thousand seed weight (0.55**), seed yield per plant (0.65**), and seed yield per plot (0.45*). Similarly, seed weight per umbel was strongly significantly positive and moderately positively correlated with plant height (0.72**), flower stalk length (0.65**), flower stalk diameter (0.49*), number of seeds per umbel (0.83**), thousand weights (0.77**), and seed yield per plot (0.64**). This result similarly implied that the increment of umbel size causes for the increment of number of seeds per umbel and seed yield per plant and per hectare. This result is in accordance with the findings of Limeneh et al. (2019) and Tamrat (2006).

Table 3: Simple correlation between yield, yield components and growth character of onion

variable	DB	DF	DM	PH	FL	FD	NFPP	UD	NSPU	S WPU	TSW	SYPT	SYPP	SYPH
DB	1													
DF	0.55**	1												
DM	0.58**	0.48**	1											
PH	-0.53	-0.71	-0.39*	1										
FL	-0.48	-0.68	-0.32	0.97**	1									
FD	-0.20	-0.47	-0.20	0.78**	0.81**	1								

NFPP	-0.57	-0.40	-0.33	0.39*	0.30	0.00	1							
UD	-0.26	-0.53	-0.19	0.85**	0.83**	0.85**	0.19*	1						
NSPU	-0.58	-0.60	-0.41	0.78**	0.76**	0.59**	0.49**	0.65**	1					
SWPU	-0.63	-0.62	-0.64	0.72**	0.68**	0.49**	0.49**	0.55**	0.83**	1				
TSW	-0.66	-0.67	-0.62	0.72**	0.65**	0.50**	0.61**	0.55**	0.82**	0.77**	1			
SYPT	-0.59	-0.58	-0.46	0.69**	0.60**	0.52**	0.50**	0.61**	0.75**	0.72**	0.81**	1		
SYPP	-0.58	-0.61	-0.45	0.61**	0.52**	0.34*	0.58**	0.45**	0.69**	0.64**	0.80**	0.84**	1	
SYPH	-0.43**	-0.47**	-0.37*	0.47**	0.41**	0.28*	0.37*	0.34*	0.55**	0.53**	0.68**	0.67**	0.83**	1

**, **, and ns indicate significant, highly significant, and non-significant differences at probability levels of 5% and 1%, respectively, and DB, DF, DM,PH,FL,FD,NFPP,NUPP,UD,NSPU, SWPU, TSW, SYPT, SYPP, and SYPH=days to 50% bolting, days to 50% flowering, days to 50% maturity, plant height, flower stalk length, flower stalk diameter, number of flower stalk per plant, number of umbel per plant, umbel diameter, number of seed per umbel, seed weight per umbel, thousand seed weight, seed yield per plant, seed yield per plot, and seed yield per hectare, respectively.*

4.5. Partial Budget Analysis

A partial budget is a way to arrange information regarding the costs and benefits of different treatments as well as experimental results. It involves focusing mainly on the expenses, benefits, and resource requirements that would change as a result of the suggested adjustment. A partial budget can be used to determine the net benefits of each treatment as well as the total costs that vary (CIMMYT, 1988).The average yield of 15 treatment was determined based on the study's findings. As per CIMMYT (1988), a 10% downward adjustment was made to the average yield. This is because average yields should be reduced because researchers believe that, even with the same treatments, the yields from farmers' fields and experimental plots differ. In order to determine the net yield, the suggested value of 10% was adjusted from each of the 15 treatments. Additionally, it is essential to understand the field cost value of one kilogram of onion seed during harvest season in order to calculate the gross field benefits. Finally, the gross field benefit of onion seed was calculated by multiplying the adjusted yield by the field price. The net benefits and total costs for each combination of treatments were computed. The costs associated with this experiment depend on the treatment, and these costs include those related to nitrogen (urea), bulbs, and labor for applying nitrogen fertilizer and transportation bulbs. The cost to purchase the bulb was 90.00 Birr kg, and the urea was 55.00 Birr kg. During the season, a day's labor would cost 300 birr. During the harvest season, the field price per kilogram of onion seed was 3000 birr. The cost of onion seed was exceptionally high (3000 birr per kg) from the normal market, and this was one reason for the high net benefit recorded in this study.

The partial budget analysis showed the highest net benefit of Birr 4550120 with higher cost (804646.96 Birr) was recorded from the combination of nitrogen at rate of 69 kg ha^{-1} and large mother bulb size (5.1-6 cm) cm with marginal rate of 56.88%, which was followed by net benefit of Birr 4438704 from rate of nitrogen of 92 kg ha^{-1} and mother bulb size of 4.1-5 cm with marginal rate of 7975% and with least cost production of about Birr 608796. This means that for every Birr 1.00 invested in 92 kg ha^{-1}N ha-1 and 4.1-5 cm bulb size, growers can expect to recover the Birr 1.00 and obtain an additional 79.75 Birr. The minimum acceptable marginal rate of return (MARR %) should be between 50% and 100% CIMMYT (1988). Thus, the current study indicated that the marginal rate of return is higher than 50%. Hence, the most economically attractive combinations for small-scale farmers with low cost of production and higher benefits were in response to the application of 69 kg N ha^{-1} and 5.1-6cm bulb size.

Table 14: partial budget analysis for seed production of onion as affected by nitrogen and mother bulb size in experimental site in Laelay Maychew district during 2023/24 G.C

N (kg $^{ha-1}$) with Bulb Size (cm) combination	Average Yield (kg^{ha-1})	Adjusted yield (kg $^{ha-1}$)	Gross Field Benefit (ETB)	Total cost (ETB)	Net benefit (ETB)	Marginal rate of return (%)
3-4*0	1042	937.8	2813400	298303	2515097	0
3-4*23	1398.4	1258.56	3775680	301353	3474327	31450
3-4*46	1494	1344.6	4033800	304403	3729397	8363
3-4*92	1602	1441.8	4325400	310503	4014897	4680
4.1-5*69	1778.3	1600.4	4801200	605746	4195454	61.1
4.1-5*92	1869.5	1682.5	5047500	608796	4438704	7975.4
5.1-6*69	1983.25	1784.9	5354700	804646.96	4550120	56.88

CONCLUSION AND RECOMMENDATIONS

The rate of nitrogen and mother bulb size influenced growth, yield and yield component of onion seed grown in the study area. Days to 50% bolting, plant height (cm), flower stalk length (cm), flower stalk diameter (mm)**,** number of flower stalks per plant, umbel diameter (mm), and seed yield per hectare (kg) were significantly affected by the main effect of mother bulb size and rate of nitrogen. Moreover, the interaction effect of nitrogen fertilizer rate and mother bulb size significantly influenced days to 50% flowering, days to 50% maturity, number of seeds per umbel, seed weight per umbel, thousand seed weight, seed yield per plant, and seed yield per plot. However, flower stalks diameter and umbel diameter significantly influenced only by the main effect of nitrogen rate. Significantly earlier in days to 50% bolting was obtained from mother bulb sizes of 5.1-6 cm and 69 kg ha^{-1} nitrogen fertilizer rates. Likewise, the lowest or earlier in days to 50% flowering and days to 50% maturity were recorded in the treatment combination of 5.1-6 cm large mother bulb size and 69 kg ha^{-1} nitrogen rate. Significantly taller plant height was obtained at the mother bulb size of 5.1-6 cm and 69 kg and 92 kg ha^{-1} nitrogen fertilizer rate. The maximum flower stalk height was recorded for nitrogen application at the rate of 69 kg ha^{-1} and bulb size (5.1-6 cm).Similarly, the flower stalk diameter was produced in the onion plant that received nitrogen at rates of 92 kg ha^{-1} and medium bulb size. The lowest seed weight per umbel was obtained from 3-4 cm small mother bulb size (0.92 g) without nitrogen fertilization. The highest number of flower stalks per plant was produced from 69 kg ha-1 rate of nitrogen and 4.1-5 and 5.1-6 cm mother bulb sizes. Likewise, the highest umbel diameter was recorded from the plant that was treated with 92 kg N ha^{-1} and medium bulb size. Maximum numbers of seeds per umbel were recorded from the treatment combination of 5.1-6 cm mother bulb size along with nitrogen fertilizer application of 69 and 92 kg ha^{-1}. The highest seed weight per umbel was obtained from the 5.1-6 cm large mother bulb size (2.32 g) at the rate of 69 kg ha^{-1}, but seed weight per umbel decreased to 1.79 g as the nitrogen level increased to 92 kg ha^{-1}.

Likewise, maximum thousand seed weights were recorded from the treatment combination of 5.1-6 cm mother bulb size along with 69 ka ha^{-1} rate of nitrogen fertilizer. Onion plants that received 69 kg N ha^{-1} at the mother bulb size of 5.1-6 cm had the maximum (17.20 g) seed yield per plant. Seed yield per plot was significantly higher (1197.91) in response to the nitrogen dose of 69 kg ha^{-1} and at the larger mother bulb size (5.1-6 cm). Significantly, the highest seed yield per hectare (1983.25 *kg* ha^{-1}*)* was recorded from treatment combination of large bulb sizes of 5.1-6 cm and 69 kg ha^{-1}.In general all the tested growth, yield and yield component of onion seed were increased with increasing mother bulb size and rate of nitrogen up to 69 kg $ha^{-1}$and where plants supplied by 69 kg ha^{-1} as well as those planted at 5.1-6 cm mother bulb size recorded were best in most parameters. On the other hand, the highest (1762.55kg/ha^{-1}) onion seed yields were obtained by the treatment combination of 92 kg ha^{-1} nitrogen and large mother bulb size 5.1-6 cm.

According to the partial budget analysis of the marginal rate of return and net benefit ratio, large mother bulb size 5.1-6 cm with 69 nitrogen kg ha^{-1}fertilization was the most profitable. Since the combination of 69 kg ha^{-1} nitrogen with and large mother bulb size (5.1-6 cm) recorded maximum net benefit (4550120), it can be recommended for Onion seed producers in the study area and should be encouraged to apply nitrogen fertilizer at the rate of 69 kg ha^{-1} and 5.1–6 cm mother bulb size to produce a better seed yield of onions. However, as the experiment was done for only one season and single location, Therefore, it is necessary to repeat the experiment over multiple seasons and locations to confirm these recommendations and draw more conclusive results.

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APPENDICES

Appendix Table 1 Analysis of variance (mean square) of the data for plant height, days to 50%bolting, days to50 % flowering, days to50% maturity, flower stalk length and flower stalk diameter

Source of Variation	Degree of Freedom	Mean square values					
		PH	50% DB	50% DF	50% DM	FL	FD
Replication	2	1.3	0.69	0.28	2.42	15.2	1.22
Bulb size	2	62.4**	56.16***	13.42***	43.62***	21.0ns	0.25ns
N level	4	646.58***	18.64**	14.41***	7.72***	432.8***	12.65***
Bulb Size *N	8	16.1ns	1.13ns	2.39*	3.96**	11.22ns	0.32ns
Error	28	8.70	3.21	0.78	1.07	8.9	0.58
CV (%)		3.99	3.29	1.19	0.80	4.71	6.37

ns=non-significant, * and ** indicate significant difference at probability levels of 5% and 1%, respectively, PH=plant height, DB=days to 50% bolting, DF=days to 50% flowering, DM=days to 50% maturity, FL=flower stalk length, FD=flower stalk diameter.

Appendix Table 2: Analysis of variance (mean square) of the data for Number of flower stalks per plant, Umbel Diameter (mm), and Number of seeds per umbel

Source of Variation	Degree of Freedom	Mean square values		
		NFPP	UD	NSPU
Replication	2	4.09	15.15	2348
Bulb size	2	16.30***	1.78ns	63098***
N level	4	1.50ns	40.53***	94552***
Bulb Size *N	8	0.75ns	4.13ns	7257**
Error	28	0.90	3.67	1961
CV (%)		11.88	4.86	12.03

ns=non-significant, * and ** indicate significant differences at probability levels of 5% and 1%, respectively. NFPP=number of flower stalks per plant; NUPP= Number of umbels per plant; UD= Umbel Diameter (mm); NSWP= Number of seeds per umbel

Appendix Table 3: Analysis of variance (mean square) of the data for seed weight per umbel, 1000 seed weight, seed yield per plant, seed yield per plot, and seed yield per hectare

Source of Variation	Degree of Freedom	Mean square values				
		SWPU	1000SW	SYPT	SYPP	SYPH
Replication	2	0.06	0.0202	7.98	35892	16292
Bulb size	2	1.12***	1.944 ***	37.99 ***	256029***	750873***
N level	4	0.93***	0.944***	45.85***	132092***	412350**
Bulb Size *N	8	0.10*	0.0996**	4.41*	30000**	147285*
Error	28	0.032	0.0269	1.59	8450	69464
CV (%)		12.59	5.45	9.44	9.65	17.08

ns=non-significant, * and ** indicates significant difference at probability levels of 5% and 1%, respectively, SWPU=seed weight per umbel;1000SW=thousand seed weight; SYPP=seed yield per plant; SYPP= seed yield per plot; SYPH=seed yield per hectare

Appendix Table 3 Characteristics of Adama red onion variety

Onion Cultivar	Maturity Days	Bulb Color	Bulb Shape	Bulb Size(gm.)	Bulb Yield(qt/ha)	Seed Yield
Bombay Red	120-135	Dark red	Flat globe	65-80	350	10-13

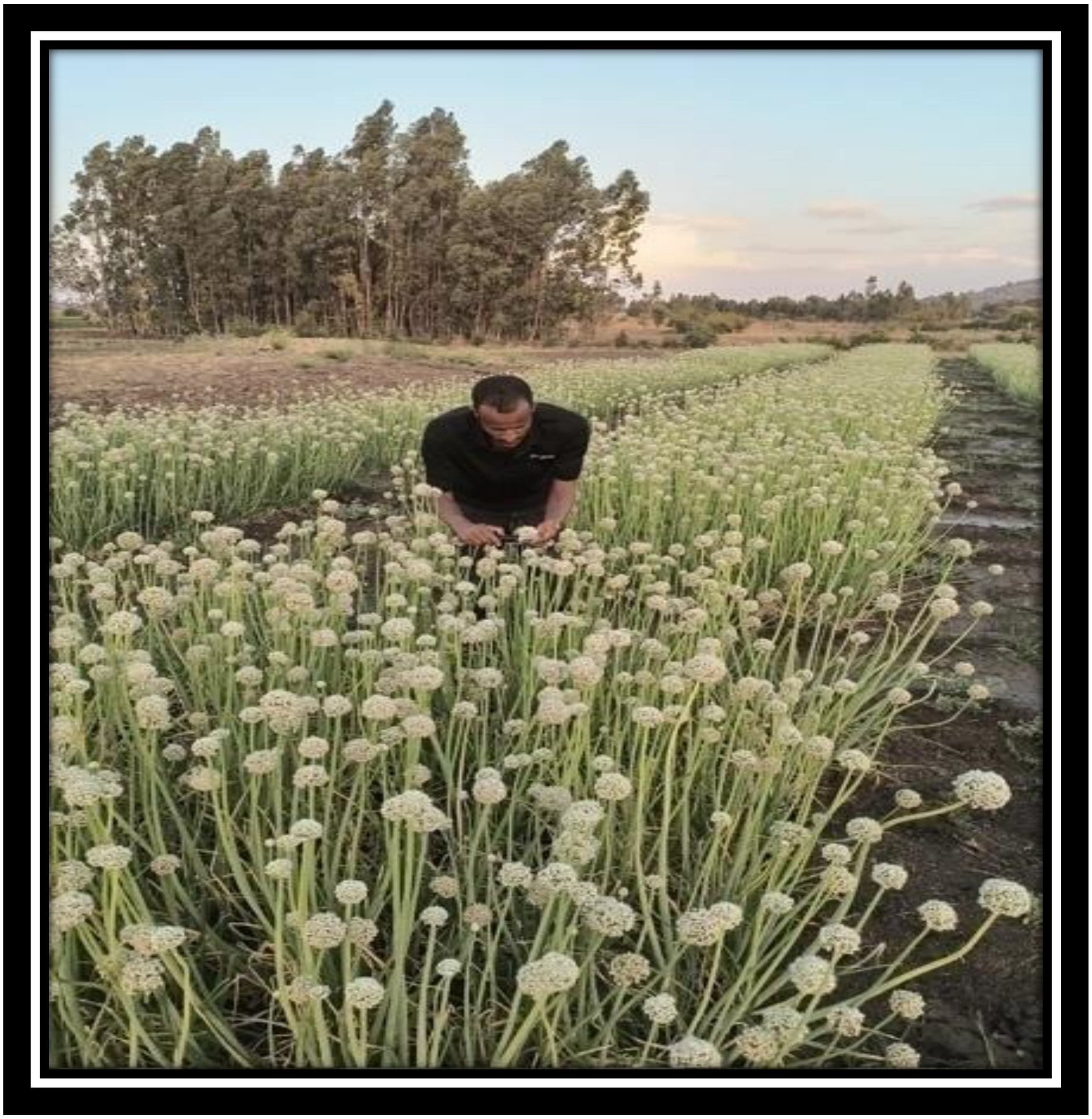
Source: Adapted from Lemma Desalegn and ShimelisAklilu (2003), Yield includes research station and farmers field report

Appendix Figure 1: Land Preparation and Layout of the Experimental Area

Appendix Figure 2: Growth stage of Onion

Appendix Figure 3: Full Flowering Onion Seed

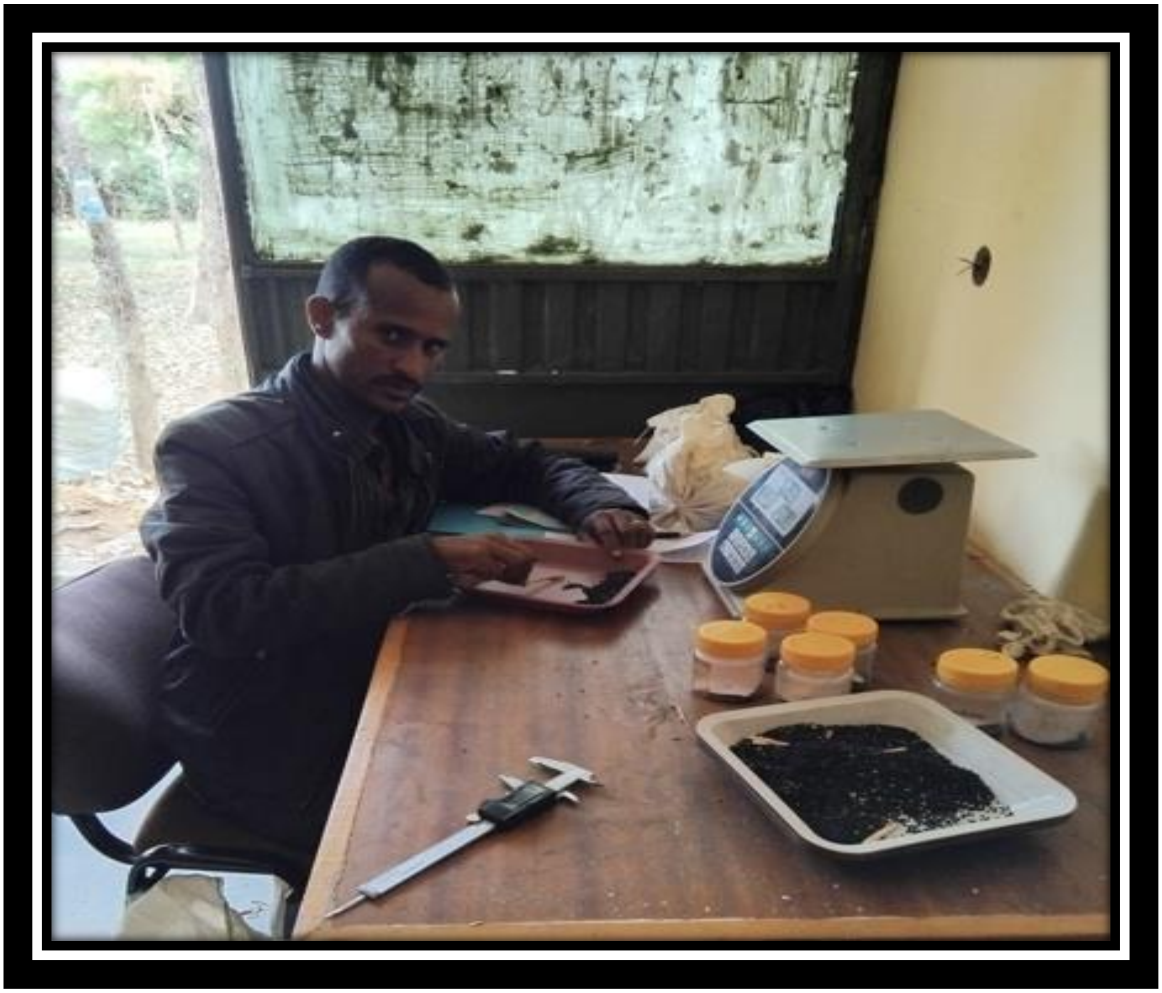
Appendix Figure 4: Measuring Umbel of Onion



Appendix Figure 5: Full flowering stage of onion

Appendix Figure 6: Harvesting of Onion Seed

Appendix Figure 7: Drying the Harvested Umbel



Appendix Figure 8: Counting and Weighting of Onion Seed

Appendix Figure 9: Cleaned Onion Seed