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Effects of Intra Row Spacing on Growth, Yield and Yield Components of Onion Varieties (Allium Cepa L.) At Jawi District, Awi Zone, Western Ethiopia

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BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIROMENTAL SCIENCE

M.Sc. PROGRAM IN HORTICULTURE

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MSc. Thesis

By

TesfayeGobezayehuTayachew

July, 2023

Bahir Dar, Ethiopia

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M.Sc. Thesis

By

Tesfaye Gobezayehu Tayachew

Submitted in partial fulfillment of the requirement for the degree of masters of Science (M.Sc.) in ''horticulture''

July, 2023

Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

As member of Board of Examiners of Master of Science (MSc.) thesis open defense examination. We have read and evaluated this thesis prepared by **Mr. TesfyaeGobezayehuTayachwu entitled "Effect of intra row spacing on plant growth, yield and yield components of onion varieties (*Allium cepa* L.) at Jawi, district, Awi zone western Ethiopia."** We here by certify that, the thesis is accepted for fulfilling the requirement of the award of Master of Science (M.Sc.) in **"Horticulture"**.

Board of Examiners

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2. HabtamuTegen (PhD) _____. 05 July 2023

Name of internal examiner Signature Date

3. MelkamuAlemayehu 07 July 2023

Name of chairman Signature Date

DECLARATION

This is to certify that this thesis entitled **"Effect of Intra Row Spacing on Plant Growth, Yield and Yield Components of Onion Varieties (*Allium cepa* L.) atJawi District Western Ethiopia."** submitted in partial fulfillment of the requirements for the award of the degree of Master of Science (MSc.) in **"Horticulture"** to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. TesfayeGobezayehu (ID. No. BDU 1301106R)** is an authentic work carried out by him under my guidance. The matter embodied in this project work has not been submitted earlier for award of any other degree or diploma to the best of our knowledge and belief.

Name of the Student

Tesfaye Gobezayehu Signature ..... Date 01/July/2023

Name of Supervisor

BayeBerihun (PhD)Signature [redacted] Date 05/July/2023

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Finally, my deepest gratitude goes to my family Gobezayehu Tayachew and Bezinash Mulgeta for their prayers, support and encouragement.

DEDICATION

I dedicate this thesis manuscript to my father Gobezayehu Tayachew for his advice and for nursing me with affection and care and for his close follow up in the success of my life.

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CSA	Central Statistical Authority
EARO	Ethiopian Agriculture Research Organization
EIAR	Ethiopian Institute of Agriculture Research
LSD	Least Significant Difference
MARC	Melkasa Agriculture Research Center
MOARD	Ministry of Agriculture and Rural Development
SAS	Statistical Analysis System
MRR	Marginal rate of returns

Effect of intra row spacing on growth, yield and yield components of onion varieties (*Allium cepa* l.) at Jawi district, Awi zone western Ethiopia

By: Tesfaye Gobezayehu

Advisor: Baye Berihun (PhD)

ABSTRACT

Ethiopia has a great potential to produce onion every year for both local consumption and export market. However, the production and productivity of the crop is low compared with the world average. Among many contributing factors, lack of improved varieties and poor agronomic practices like inappropriate population density have been the major bottlenecks of onion production and productivity in Awi zone. A field experiment was carried out between November 2021 and Mar 2022 to determine the effect of intra row spacing on plant growth, yield and yield components of onion varieties (allium cepa l.) at Jawi district, Awi zone western Ethiopia. Four different intra-row spacing (4cm, 6cm, 8cm and 10 cm) combined with three onion varieties ('Bombay' Red, 'Nafis' Red, and 'Nasik' Red) were evaluated using randomized complete block design in factorial arrangement with three replications. Data on growth yield and yield component parameters were recorded and subjected to ANOVA using SAS version 9.4. The results of the present study indicated that the variety and intra row spacing highly significantly influenced while their interaction effect had not significantly affected the tested parameters of onion. The intra-row spacing of 10 cm was significantly superior in terms of plant height, leaf number per plant, leaf length, percentage of bolters, bulb length and bulb diameters. Similarly, the highest Average bulb weight (75.22 g) was recorded with10 cm intra row spacing while the minimum average bulb weight (43.05g) was recorded with the closest intra-row spacing of 4 cm. The highest marketable bulb yield (33.18 tons ha^{-1}) was recorded from the variety Bombay red at 4 cm intra row spacing. Similarly the highest harvest index (94.28%) was recorded from the variety 'Bombay' Red at 4 cm intra row spacing. Moreover, the result revealed that 'Bombay' Red variety is bitter than Nasik and Nafis red variety in bulb yield on intra-row spacing at 4 cm can give good yield of onion. The partial budget analysis revealed that the highest net benefit with highest marginal rate of returns was obtained in Bombay red at intra-row spacing of 4 cm (633435.1birr $ha^{-1}$and 599.86%) respectively and recommended for economic production of onion in the study area. As a follow up work, multi-location and multi season research could be suggested to come up with full recommendation.

Key words: Onion varieties, intra-row spacing, bulb yield.

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Chapter 1: INTRODUCTION

1.1. Background and Justification

Onion (*Allium cepa L.*) belongs to the family Alliaceae and genus Allium which is originated in south-west Asia and Mediterranean regions. The genus Allium contains about 750 species; among these onion, leeks and garlic are the most important once Gessesew Seifu *et al*., (2015). It is herbaceous biennial but cultivated as an annual crop for bulb production. Onion is one of the most important monocotyledonous, cross-pollinated and cool season bulb vegetable crops produced throughout the world. Currently, onion is produced in more than 130 countries throughout the world Robinowitch and Currah, (2002).

It is one of the main sources of flavonoids in the human diet and the use of flavonoid has been linked to reduced risk of cancer, heart disease and diabetes. Moreover, it is known for its anti-bacterial, anti-viral, anti-allergenic and anti-inflammatory properties (Brewster and Rabinowitch, 1990).

According to FAO (2019) report a total of 99,968,016 tons of onion is produced worldwide with the global average of 19.25 tons ha^{-1}. China is the largest onion producer country in the world with 24,966,366 tons production volume per year. In Africa, Egypt is the top onion producer country with 3,081,047 tons production (FAOSTSAT. 2019).

In Ethiopia, onion is one of the most important cool season bulb crop produced by smallholder farmers mainly as a source of cash income (Lemma Dessalegn and Shimeles Aklilu, 2003). The crop is very essential in the Ethiopian diet daily, which is widely consumed as a spice and or vegetable in strews (MoARD, 2009; Kubsa *et al.,* 2006).

Ethiopia's diversified agro-climatic conditions suitable for successful production of onion (Lemma *et al.,* 2006). However, the best growing altitude for onions under Ethiopian condition is between 700 and 1800 m above sea level (Lemma Dessalegn, 2004).

In Ethiopia, onion is an important economic center of the production, high yield per unit area and availability of small-scale irrigation. During 2019 growing season 734,921 small holders are engaged in onion production. The total area allocated to onion has reached 36,373.48 ha; with a total production of 273,858.986 tons and average productivity 7.53 tons ha^{-1} which is low as compared with the world average productivity 19.25 tons ha^{-1} (FAOSTSAT. 2019); CSA. 2019).

Different cultural practices, varieties and growing environments are known to influence growth, yield and yield components of bulbs. Poor agronomic practices such as, in appropriate use of plant spacing, lack of improved varieties adaptable across a wider agro ecologies, diseases and insect pests, insufficient extension services, and high costs of agricultural input are all factors that contribute to low onion crop yield in Ethiopian Shura, *et al.,* (2022); Rahel Demisie and Kassaye Tolessa (2018).

To improve onion production, the agricultural research system of the country has made efforts to generate improved varieties. 'Bombay' Red and 'Adama' Red varieties are recommended and widely grown in Ethiopia. However, these varieties are limit distributed to some growing areas of the country and are low tested in some agro-ecologies particularly in the study area Yemane Kahsay *et al.,* (2014). It is very difficult to give general recommendation that can be applicable to all agro ecological zones. In order to optimize onion productivity, full package of information is required for specific production belt Gupta *et al.,* 1994; Lemma Dessalegn and Shimeles Akelilu, (2003).

Plant spacing is one of the important agronomic practices that control bulb size, shape and yield. The effect of spacing varies on the performance of onion varieties as their roots and vegetative growth habits are different. Plant density affects bulb yield and yield components of onion. Plant population density is one of the agronomic practices that need to be optimized so as to improve the production and productivity of onion. The optimum use of spacing or plant population has dual advantages. It avoids strong competition between plants for growth factors such as water, nutrient and light. In addition optimum plant population enables efficient use of available cropland without wastage (Geremew Awas *et al.,* 2010). The higher yield and better control of over or under bulb size could be obtained if plants are grown at optimum density.

Geremew Awas *et al.(*2010), recommended intra row spacing of 4 cm for 'Nasik' Red and 'Adama' Red varietiy, and 6 cm for 'Bombay' Red variety, both of which gave highest marketable yield and reduced unmarketable bulb yield in central rift valley areas of Ethiopia. According to Kantona *et al.* (2003), variety as well as planting densities significantly affected the onion bulb yield.

1.2. Statement of the problem

The current status of onion production in Awi Zone, Jawi district is found at lowest stage which is less than 300 ha with average productivity 5.5 tons ha^{-1} which is low compared to the national average yield (7.53tons ha^{-1}) (CSA, 2019). Unavailability of adaptable onion varieties and lack of proper agronomic practices used by farmers are the major problems in onion production in the study area. Farmers in the study area are growing only Bombay red onion variety (Rahel Demisie and Kassaye Tolessa 2018).

Although, various open pollinated and hybrid onion varieties are available in the country less introduce and low test them for their adaptability and yield performance in Jawi district. Similarly farmers in Jawi are using different intra-row spacing for onion production. Different intra-row spacing recommendations have been suggested for different onion varieties in different parts of the country, particularly in rift valley areas. However, these recommendations may be affected by environmental variations. Moreover, current market preference on bulb size and variety of onion necessitates an evaluation of the response of yield and bulb size to plant population for specific onion growing areas. Hence recommendations on improved agronomic practices like spacing, combined with different onion varieties should be suggested so as to enhance the productivity of onion in the study area. Therefore, this field research was conducted to determine the optimum intra row spacing and to select adaptable onion varieties advisable so as to increase the production and productivity of onion in the study area.

1.3. Objective

1.3.1. General objective

The general objective of the study was to contribute the production and productivity of onion through developing appropriate agronomic practices for the available varieties in the study area.

1.3.2. Specific objectives

- To investigate the effects of intra-row spacing on the growth, yield and yield component of onion varieties.

- To determine the optimum intra- row spacing for economically feasible onion production of the study area.

Chapter 2: LITERATURE REVIEW

2.1. Origin and botany of onion

The primary center of origin of onion is central Asia with secondary center in Middle East and Mediterranean Region. Onion is one of the most ancient vegetable crops under cultivation. It has been widely distributed to various countries of the world. Currently onion is grown in at least 170 countries of the world (Grubben and Denton, 2004).

The crop is highly cross-pollinated. The intensity of cross pollination varies between 30 to 90% depending on availability of pollinators. The pollen usually sheds before the female part is receptive (Protoandry) and this makes self-pollination difficult. Depending on the cultivars, the number of flower stalks produced by a single onion dry bulb varied from 3 to 12 flower stalks and it produces about 250 to 1000 flowers per umbel under Melkassa conditions Lemma Dessalegn, (2004). Onion is a flowering plant, an angiosperm. The plant body of angiosperms mainly is saprophytic. Hence, in their plant body, all cells are diploid in nature; that is to say, there are two sets of chromosomes. The chromosome number is 2n = 16. Peter Firbas & Tomaž Amon (2014)

Onion is a shallow rooted, biennial crop which is grown as annual. The leaves are long, overlapping bases. The tubular leaf blades are flattened on the upper surface, and the stem of the plant also is flattened. Roots arise from the bottom of the growing bulb. Leaf initiation stops when the plant begins to bulb. The base of each leaf becomes one of the “scales” of the onion bulb, so the final bulb size depends in part on the number of leaves present at bulb initiation. The leaf base begins to function as a storage organ at bulb initiation, so the size of the leafy part of the plant also influences bulb size. Thus, the more leaves present and the larger the size of the plant at the onset of bulb initiation, the larger will be the bulbs and the greater will be the crop yield (Hamasaki *et al.,* 1999).

2.2.1. Onion Bulb Initiation and Formation

Onion plant will first form the leaf and then, depending on the onion variety and length of daylight start to form the bulb by swelling of the lower leaf parts. It is a long day plant characterized by day length onion varieties will stop forming tops and begin to form bulbs when the day length reaches 14

to 16 hours, with a critical minimum day length of 12+1 hours Williams *et al.*, (1991); Rice *et al.*, (1993). Bulb initiation is an indicator of growth and development of the crop Jones and Mann, (1963). Roots of onion produced from base plate. New roots form irregular rings above and around the older ones and emerge through the corky outer tissue.

The leaf plant eventually ceases to form leaf blades, and instead the apex begins to initiate a number of bladeless, concentric, thickened leaf sheaths. This process leads to form the bulb scales Brewster and Rabinowitch, (1990). The swollen lower leaf sheath of older leaves develop to fleshy part of the onion bulb. During bulbing, most of the assimilated dry matter is transferred down to the bulb and contributing to the swollen leaf sheaths and to the bladeless fleshy scales Brewster, (1997).

2.3. Environmental requirements of onion

Onion can be grown in a wide range of climatic environments, but it grows best at mild climate without excessive rainfall or extremes of heat and cold. Onion is a cool season crop that has some frost tolerance but is best adapted to a temperature range between 18^0 and 27^0C. An optimum temperature for the production of onion ranges from 18 to 27°C. Temperatures below the optimum ranges caused bolting of plants consequently reduced bulb yield. Similarly temperatures above 30°C lead to early maturity of the plant and reduced bulb yield Lemma Dessalegn, (2006).

Onions can be grown on a wide range of soils, varying in texture from coarse-grained sands to clays. Soils should be 45-60 cm deep and well drained. Soils with high water holding capacity is better able to provide moisture to the shallow rooting system but must also drain well to be suitable. Growth is retarded when available soil moisture is low, but onions are also sensitive to a high water table or water logging Lemma Dessalegn, (2006).

Highest yield can be obtained from freely drained friable loam soil with pH of 6.2. Due to buildup of soil borne diseases, it should be, rotated with unrelated crops such as beans, cereals, etc. Onion could be, planted at an interval of 3 to 4 years Lemma Dessalegn, (2004). Onion is also sensitive to highly acid soils and grows best when the pH is 6.2 Raemaekers, (2001)

2.4. Effects of Intra row Spacing on Growth, Yield and Yield Components of Onion.

Plant population refers to number of plants per unit area and is important in onion production since it has an influence on growth and yield of onion bulbs. Plant population affects interplant competition towards the growth factors like water, nutrient and light, which influences growth and development of plant (Brewster, 2008). The intra row spacing has significant effect on the growth parameters of onion. With the increasing intra row spacing the days to bulb maturity, plant height, leaf length and leaf number of onion also increased Habtamu Tegen *et al.,* (2016).

The leaf length of onion significantly influenced by intra row spacing The maximum leaf length (43.68 cm) was recorded in plants spaced at 20 cm (43.14 cm) as compared to the closet plant spacing of 10 cm. Jilani *et al.*, (2010). Similarly, Belay *et al.* (2015) and Guesh Tekele (2015) reported that the leaf length of onion increased with the increasing intra row spacing. The leaf number also significantly affected by intra row spacing

With the increasing of plant spacing the leaf number per plant of onion also significantly increased Guesh Tekle, (2015); Habtamu Tegen *et al.* (2016); Kiros Gebretsadik and Nigussie Dechassa (2018) According to Nigullie and Biawas (2017) the maximum leaf number was recorded on the widest intra row spacing compared to the narrowest intra row spacing. Bolting may vary due to genetic factors and changes in temperature affecting the growth, relative length of day and night, spacing, and seedling size Salunkhe, (1998).

The intra row spacing has significant effect on the yield and yield components of onion. With the increasing intra row spacing the bulb length, bulb diameter and bulb weight of onion also increased Rahel Demisie (2018); Yemane Kahsay *et al.*, (2013). Similarly, Asres Derejew *et al.*, (2017) reported that the average bulb length, bulb length and bulb diameter of onion increased with the increasing intra row spacing. The higher bulb length (6.02 cm) from plants grown in wider spacing of (15 cm) and the smaller bulb length (5.48 cm) was obtained from closer spacing (7.5 cm) spacing. The intra arrow spacing has significantly affected bulb diameters. Wider intra row spacing recorded highest bulb diameter Nigullie and Biawas *et al.*,(2017); Kitila Chala *et al.,* (2021).

Similarly, Rahel Demisie (2018) recorded the highest bulb diameter (5.63 cm) when onion plants were spaced at 13 cm intra-row spacing followed by 10 cm intra-row spacing (5.50 cm). With increases of intra row spacing has significant effect of average bulb weight. Wider intra row spacing recorded highest average bulb weight Nigullie and Biawas (2017). As an intra-row spacing increased from 10 to 15 cm of average bulb weight from 41.97 to 92.2 g Weldemariam Seifu *et al.,* (2015). According to the finding of various researchers decreasing the intra row spacing results significantly decrease in bulb length, bulb diameter and bulb weight of onion Hosmani *et al.,* (2010); Yemane Kahsay *et al.,* (2013).

The intra row spacing has significant effect on the marketable bulb yield, unmarketable bulb yield, total bulb yield and harvesting index. As intra row spacing increases the marketable bulb yield decreases Nigussie Dechassa (2018); Rahel Demisie and Kassaye Tolessa (2018). According to Simon *et al.* (2014) the highest marketable bulb yield (38.93 tons ha^{-1}) was obtained from plants grown at 7 cm intra-row spacing. An intra-row spacing 13 cm showed the lowest marketable bulb yield (25.21tons ha^{-1}). Wider intra row spacing recorded lower unmarketable bulb yield. With the increase in the intra row spacing unmarketable bulb yield of onion decreased Asers Derejew *et al.* (2012); Gushu Tekle (2015); Kiros Gebretsadik and Nigussie Dechassa (2016).

The intra row spacing has significant effect of total bulb yield. The highest total bulb yield from densely populated onion plants than sparsely planted ones Nigullie and Biawas (2017). Similarly, Yemane Kahsay *et al.* (2013), who reported that the highest total bulb yield, were achieved at 5 and 7.5 cm intra-row spacing, respectively as compared to the 10 cm intra-row spacing. Mekdes Ataklt 2012; Yemane *et al.,* (2013) for onion, and Asers Derejew *et al.,*(2012), for shallot who reported that wider intra-row spacing resulted in lower harvest indices. In other findings the highest marketable bulb yield, unmarketable bulb yield and total bulb yield was obtained from densely populated onion plants than sparsely planted ones Kiros Gebretsadik and Nigussie Dechassa (2018); Rahel Demisie and Kassaye Tolessa (2018).

2.5. Effects of Varieties on Growth, Yield and Yield Components of Onion

Onion cultivars vary in vegetative characteristics such as foliage length, leaf arrangement (erect, pending) and leaf color. They also differ in bulb characteristics, internal structure (single, double, multiple) bulb shape (flat to cylindrical to spindle), color (red, yellow, white), flavor rate (sweet, mid pungent and pungent. The onion genotypes also differ in ease of seed stalk development and kinds of physiological defects like splitting, doubling, thick necks and pre mature bolting. There is a strong local preference for red bulb color and high pungent with long shelf life Lemma Dessalegn and Shimelis Akelilu (2003). Varieties of onion differ in maturity. Bombay Red variety was found to be the earliest, which matured 23 days earlier than Adama Red followed by Melkam which was earlier by 18 days than the Adama Red. Bombay Red and Adama Red matured by less than 120 or/and in between 110 to 130 days, respectively (EARO, 2004; Yemane Kahsay *et al., (*2014); JamboAsfaw and Wassu Muhammad (2015).

Varieties differ in plant height, leaf length, leaf number and bolters of onion. The maximum height of plants was observed from the Nafis red, adama red and then Bombay Red variety Simon *et al.* (2014). Variety Nafis gave the highest (64.33 cm) and Melkam recorded the lowest (59.70 cm) plant height Rhail Demise and Kassaye Tolessa (2018). The highest leaf number (10.55) was recorded on Nafis variety and the plants with the lowest number of leaves (8.84) were recorded in Adama red variety Kitila Chala *et al.,* (2021).

The variety of Adama Red (40.75cm) showed longest leaf length than Melkam (37.83cm) and Bombay Red (35.17cm) Yemane Kahsay *et al.,* (2014). Cultivars variation in time of inflorescence initiation in two onion cultivars in bolting Khalid (2009).The highest bolting percentage was recorded for “Bombay Red” cultivar (Walle Tegbew *et al.,* (2018).

Varieties also differ in bulb length, bulb diameter, bulb shape index and average bulb weight. The longest bulb length were observed from Nasik red (4.41 cm) followed by Robat (4.13 cm) variety, respectively Wubetie Adnew *et al.,* (2022). The largest bulb diameter was recorded from variety Bombay Red than Nasik red variety at Fogera district Dessie Getahun *et al.,* (2020).

Similarly, Awoke Ali *et al.,* (2021) reported that the widest bulb diameter was measured from variety Bombay Red (5.67 cm) while the narrowest bulb diameter was obtained from variety Adama Red (5.18cm) followed by variety Melkam (5.32 cm). Bulb shape difference among onion cultivars was affected by environmental conditions. Bombay' Red variety produced the minimum bulb shape index (1.10) as compared to 'Nasik' Red which produced higher Mekdes Ataklt (2012). Variety has significant effect of average bulb weight. Higher fresh bulb weights of 126.4 g and 121.8 g were observed from varieties Bombay red and Nafs respectively, which differed insignificantly from varieties Nasik red (119.5 g) and Robaf (115.5 g). The lowest dry bulb weight of (102.8 g) was observed in variety of Adama red Gezahegn Fikre *et al.,* (2021).

A variety has significant effect of marketable bulb yield, unmarketable bulb yield, total bulb yield and harvesting index. The highest marketable bulb yield (32.90tons ha^{-1}) was recorded from variety 'Bombay' Red and the lowest marketable bulb yield (30.35tons ha^{-1}) was obtained from the variety 'Nasik' Red Mekdes Ataklt (2012). The highest unmarketable bulb yield (1.75 tons ha^{-1}) was obtained from the control variety shallot followed by Nasik red (1.19 tons ha^{-1}) and while the least values were recorded from Robat with (0.79 tons ha^{-1}) Wubetie Adnew *et al.,* (2022). Variety has significant effect of total bulb yield. The varieties could have different yield potential in different agro ecologies due to their genetic potential and genotype by environment interaction effect Jilani *et al.,* (2009). The highest total bulb yield (35.22tons ha^{-1}) was recorded from variety 'Bombay' Red and the lowest total bulb yield of (19.50 tons ha^{-1}) was obtained from the variety 'Nasik' Red. Mekdes Ataklt (2012).

2.4. Interaction effect of intra row spacing and varieties on growth and yield

The interaction effects of different intra-row spacing and varieties had considerable influence on different parameters such as days to maturity, leaf number and bulb length. According to Kitila Chala *et al.* (2021) Adama red variety was reached at early physiological maturity (132.2 days) at narrow spaced of 6cm while the Nafis varieties were lately matured (146 days) at wider spaced of 12cm. The highest leaf number (13.7 cm) was obtained from variety Nafis with intra-row spacing of 13 cm while the lowest (7.8cm) was from variety Adama Red with intra-row spacing of 7cm Rahel Demisie and Kassaye Tolessa (2018).

The maximum (10.66) number of leaves per plant was obtained from the variety NHRDF L-28 with spacing 15x10cm. And the minimum (8.00) number of leaves per plant was obtained from the variety Agrifound Light Red with spacing 7.5x10cm Kishor Saurabh *et al.,* (2017). However, the longest length of bulb (6.86 cm) was recorded from the variety Agrifound Light Red with spacing 15 x 10 cm followed by variety NHRDF Red-3 with 15x10cm cm (6.53 cm) and the lowest bulb length (4.86 cm) was recorded from the variety Agrifound Light Red with spacing 7.5 x 10 cm Kishor Saurabh *et al.,* (2017).

The interaction effects of different intra-row spacing and varieties had considerable influence on average bulb weight, unmarketable bulb yield and harvesting index. The highest average bulb weight (63.75 g) was recorded for 'Bombay' Red variety, while the lowest average bulb weight (53.13 g) was recorded by 'Nasik' Red variety with spacing of 4 cm. And the highest unmarketable bulb yield was produced at narrow intra-row spacing of 4 cm (4.31tons ha^{-1}) and closely followed by 6 cm spacing (3.81 tons ha^{-1}) for 'Nasik' Red whereas, the lowest unmarketable yield was recorded by 'Bombay' Red at wider, 8 cm and 10 cm spacing (0.96 and 0.63 tons ha^{-1}) respectively Mekdes Ataklt (2012).

The highest total bulb yield (35.22tons ha^{-1}) was recorded from the variety 'Bombay' Red with spacing of 4 cm and the lowest (19.50 tons ha^{-1}) from the variety 'Nasik' Red at 10 cm spacing. High harvest index was recorded at intra-row spacing and variety combination of 4 cm and 6 cm with cultivar 'Bombay' Red (88.98, 87.50%, respectively). In low harvest index was recorded at the intra-row spacing of 8 cm and 10 cm with 'Nasik' Red (70.07 and 70.97 %,) respectively. (Geremew Awas *et al.,* 2010).

Chapter 3: MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted in Amhara Region, Jawi district kebele 3 North Western Ethiopia in 2022 cropping season under irrigation conditions on farmers' field. The area is situated 650, and 149 km away from Addis Ababa and Bahir Dar city, respectively. The study area is located 11^0 07'N and 36^0 20'E latitude and longitude respectively. The altitude range of the district is 806 to 1242 meters above sea level Zeleke Teshome and Netsanet Ayele, (2015).

The area is characterized by warm humid climate with mono-modal rainfall pattern, and the average rainfall of the area is 1490 mm per annum. The annual minimum and maximum monthly temperature ranges from 16.4^0C to 32.5^0C, respectively and the soil type is Verti soils which covers more than 50% of the command area among the five categories of soil types and the pH. will be 6.2 Zeleke Teshome and Netsanet Ayele, (2015) . Over all, the study is considered to be humid with relative humidity ranging between 66 and 92% Zeleke Teshome and Netsanet Ayele, (2015).

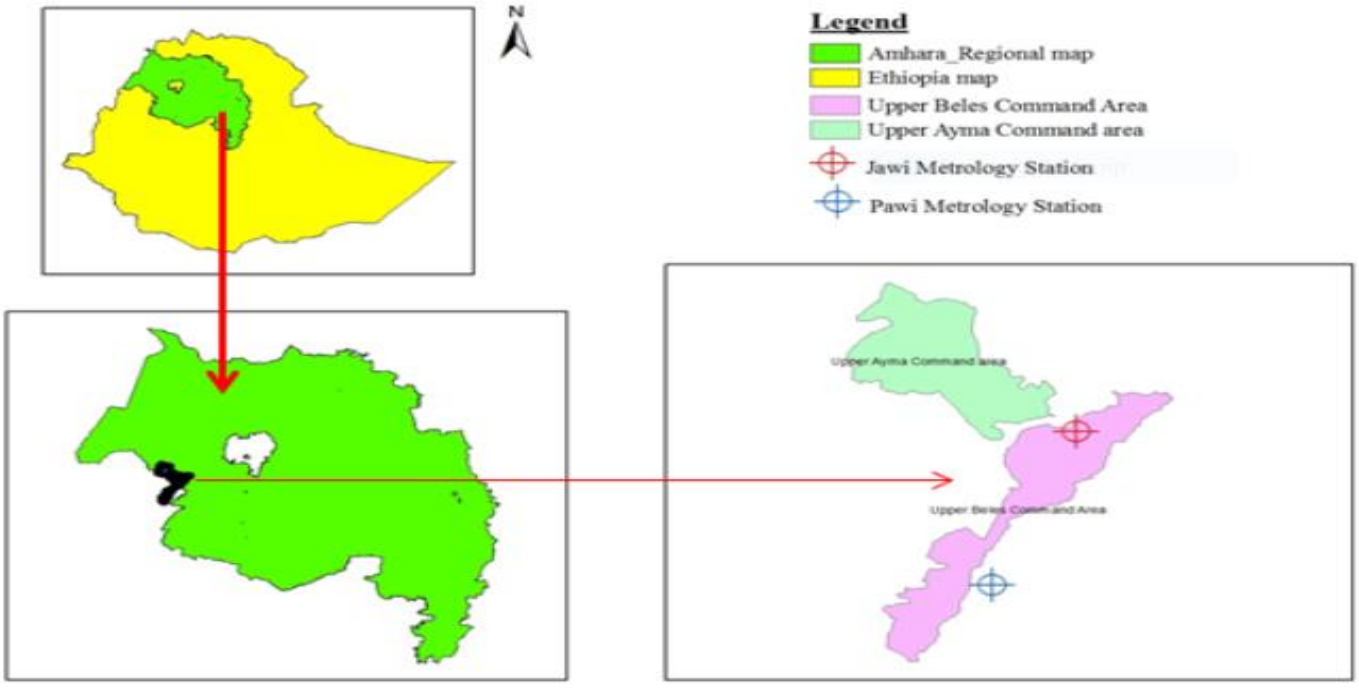

Figure.3. 1: Map of the study area

3.2. Experimental material, Treatments and Design

Bombay red, Nasik red and Nafis red onion varieties used for the study. Bombay red is one of the most commonly and widely used improved onion variety in jawi district. The color of Bombay red variety has light red bulb skin color and it is suitable for dry conditions (EARO, 2004).

The treatments consisted of three onion varieties (Bombay red, Nasik red, and Nafis red) combined with four intra rows spacing (4cm, 6cm, 8, cm and 10cm). The experiment was laid out using Randomized Complete Block Design (RCBD) in a factorial arrangement with three replications.

3.3. Experimental procedures

Each treatment combination was assigned randomly to the experimental units within a block. The onions varieties were obtained from Melkasa Agricultural Research Center (MARC). The size of each experimental plot was 2.8m^2 (1.4 m wide and 2 m long). And net plot size was 2.69 m^2, 2.63 m^2, 258 m^2, and 2.52m^2 respectively at 4 cm, 6cm, 8cm and 10cm spacing. The distances between blocks and plots were 1.5 and 1 m, respectively. The total area of experimental field was 36m length x 7.2m width (259.2m^2). The spacing between furrow, double row was 40cm and 20cm respectively.

Table.3. 1: Details description of the three onion varieties used for the study

Variety	Year of release	Maturity days	Bulb shape	Bulb yield (qt/ha)	Seed yield (qt/ha)
Bombay red	1980	90-100	Flat globe	300-400	13-20
Nasik red	2004	100-115	Globe	380	-
Nafis red	2004	100-120	Globe	350	-

Source: Adapted from Lemma Dessalegn and Shimelis Aklilu (2003), * Yield includes research station and farmers field report.

Table.3. 2: Treatment Combinations used in the study

Treatments	Treatment combinations	Population density Per plot
T1	Bombay red ×4 cm	300
T2	Bombay red ×6 cm	200
T3	Bombay red ×8 cm	150
T4	Bombay red ×10 m	120
T5	Nasik red ×4 cm	300
T6	Nasik red ×6 cm	200
T7	Nasik red ×8 cm	150
T8	Nasik red ×10 cm	120
T9	Nafis red ×4 cm	300
T10	Nafis red×6 cm	200
T11	Nafis red ×8 cm	150
T12	Nafis red×10 cm	120

3.4. Management of Experimental plants

Onion seeds were sown for nursery on 1m x 5m well prepared seed bed on October 2021 and the bed was covered with dry grass mulch until emergence (EIAR, 2007). Mulching was removed after the successful germination of the seed and the seedlings kept vigorous. The management of the seedlings such as weeding, control of disease and insect pest was preforming regularly. Watering of the seed bed was done every day in the morning using watering can (EARO, 2004).

The experimental field was ploughed, three times using oxen power. Seedlings were transplanted to the experimental plots when they attained proper stage for transplanting at 50 days after sowing and when they developed 3 or 4 leaves. Healthy, vigorous, free from disease, and insect pest damage and uniform seedling were transplanted on well prepared experimental plots at spacing of 40cm between irrigation furrows.

The management operations such as weeding, fertilization, diseases, and insect pests control were applied as per the recommendation EARO, (2004). In study area fungal diseases, aphides and trips insect are attack onion. However manage by mate Kobe and pro star chemical apply in recommendation amount 5ml chemical by 20 liter water mix. The experiment was irrigated using furrow irrigation at 3 days interval until 50 days of seedlings and at 7 days interval after establishment until maturity. However before harvesting irrigation was stopped for curing of onion bulbs at one week. NPS fertilizer was applied during planting time at a rate of (100 kg/ha^{-1}) and Urea fertilizer at the rate of (100kg/ha^{-1}) was applied in to splits the first half during planting and the second half six weeks after transplanting EARO, (2004). The crop was harvested when of the leaves turn yellow, draying, toppling of leaves Fikre Mulugeta and Nikus Olani, (2010).

3.4. Data Collected

Data were collected from the central three rows excluding the border. Individual parameters were recorded from ten randomly selected plants in the middle rows on the net plot bases except marketable bulb yield, unmarketable bulb yield and total bulb yield.

3.5.1. Phenology and growth Parameters

Days to maturity: The number of days taken from seedling transplanting up to 75% of the plants in a plot show yellowing of leaves will be counted.

Plant height (cm): plant heights of ten randomly selected plants grown in the net plot area were measured from the soil surface to the tip of the longest leaf at physiological maturity stage using a ruler and the mean was calculated.

Number of leaves per plant: The total number of fully developed leaves per plant will be counted from ten randomly selected plants at physiological maturity stage and the average will be computed.

Leaf length (cm): The leaf length will be measured at physiological maturity stage from ten randomly selected plants by using ruler and the average will be computed.

Percentage of bolters per plot: Percentage of bolter plants expressed as the number of bolter plants per plot divided by the total number of plants per plot and multiplied by 100 Mekeds ateklte (2012).

$$PB = \frac{NB}{TN} x\ 100$$

Where, PB = % of bolter plants

NB= number bolter plants per plot

TN = Total number of plants per plot

3.5.2. Yield and yield component

Bulb length (cm):- The mean length of ten randomly selected bulbs which are harvested from net plot area will be measured from the bottom to the top by using caliper.

Bulb diameter (cm): The mean bulb diameter of ten sample bulbs will be measured at the maximum wider portion of mature bulbs by using caliper.

Bulb shape index: The shape of ten randomly selected mature bulbs per plot was classified based on IPGRI descriptors for Alliums species (IPGRI, 2001). The shape index (bulb length to bulb diameter ratio) was used for analysis Mekeds Ateklte (2012).

$$\text{Bulb shape index} = \frac{\text{Bulb length}}{\text{Bulb diameter}}$$

Average bulb weight (g): The average fresh bulb weight was measured from ten randomly selected mature bulbs during harvesting by using weight balance and then expressed in gram.

Marketable bulb yield (tons/ha^{-1}): The total weight of healthy and marketable bulbs which are obtained from the net plot area was measured in kilogram by using weight balance and converted into tons per hectare.

Unmarketable bulb yield (%): The total weight of bulbs that are diseased, decayed, size and physiological disorder such as thick neck from the net plot area was measured in kilogram and expressed in percentage.

$$\text{Unmarketable bulbs (\%)} = \frac{\text{Weight of unmarketable bulbs}}{\text{Total weight of bulbs}} \times 100$$

Total bulb yield (tons/ha^{-1}): The yield which includes all marketable oversized, large, medium and small and unmarketable bulbs under sized, diseased, decay, physiological disorder such as thick necked, split and bolters weighed together and expressed as kg/plot and converted into tone ha^{-1}.

Harvest index: It was computed by dividing mean weight of 10 sample mature bulbs of plants taken edible portion by the mean total biomass of plants taken using the following equation.

$$\text{Harvest index(HI)} = \frac{\text{Edible portion}}{\text{Total biomass}} \times 100$$

3.6. Data Analysis

The mean values of the above response parameters were subjected to the Analysis of Variance (ANOVA) using SAS version 9.2 Computer software SAS Institute Inc.,(2008). Whenever the treatments were significant, least significant difference (LSD) was used for mean separation at p = 0.05.

3.7. Economic analysis

Economic analysis that comprises partial budget analysis was carried out for each treatment combination using the procedures described by CIMMYT (1988). All variable costs were calculated using the local prices of seed and labor. Moreover, the gross benefits of each treatment were calculated using the farm gate price of marketable onion bulb yield (CIMMYT, 1988).

Adjusted marketable yield (AMY): It was the average marketable bulb yield that was adjusted downward by 10% to make it comparable to the yield of farmers.

$$\text{AMY} = \text{Average marketable yield} - (\text{Average marketable yield} \times 0.1).$$

Gross benefit (GB): This was calculated by multiplying the field prices of onion that farmers would receive from the crop when they sale it as the adjusted yield.

$$\text{GB} = \text{AMY} \times \text{Field price}$$

Total variable cost (TVC): This was the summation of the cost of seed and labor costs used for the experiment.

$$\text{TVC} = \text{Seed cost} + \text{Labor cost}$$

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

$$\text{NB} = \text{Gross benefit} - \text{Total variable cost}$$

Marginal rate of return (MRR %): It was calculated as the change of net benefit divided by the change of total variable costs in the treatment as indicated by CIMMYT (1988).

$$\text{MRR}\ (\%) = \frac{\Delta \text{NB}}{\Delta \text{TVC}} \times 100$$ Where; NB = Net benefit, TVC = variable cost

Chapter 4: RESULTS AND DISCUSSIONS

4.1. Phenology and Growth Parameters

4.1.1. Days to physiological maturity

The analysis of variance revealed that the interaction effect of intra-row spacing and variety on days to maturity was not significant. However, intra-row spacing and variety significantly affected days to maturity ($p<0.05$ and $p<0.01$, respectively) (Appendix Table 1).

As intra-row spacing increased from 4cm to 10 cm, days to maturity delayed from 94.11days to 107.44days. Among the intra-row spacing, statistically similar days to maturity was obtained from 4 6 cm and 8 cm intra-row spacing 94.11 days and 97.33 days respectively (Table 4.1).

Intra-row spacing of 10 cm took longer maturity (107.44days). In general, the prolonged maturity of onion in wide spacing between plants may be attributed to the low competition for nutrient and light in wide spacing, resulting in a comfortable leaf development and delays in the maturity of bulb. Similarly, Brewster (2008) indicted that delayed days to maturity was observed from sparsely populated plants, while plants grown in closer spacing or in high plant population matured early.

Similarly Guesh, Tekle (2015), reported that plants grown at wider intra row spacing (10cm) took longer time for maturity. On the other hand, plants planted at narrower intra row spacing matured earlier. Consistent with the results of the present study, several authors Habtamu Tegen *et al.* (2016); Weldemariam Seifu *et al.* (2015), also reported that plants grown at widest intra row spacing took longer time to reach maturity while those at lowest intra row spacing matured earlier.

The early maturity (93days) was recorded by ‘Bombay Red’ Variety. The longer days to maturity (106 days) was recorded on ‘Nafis Red’ variety which is in par with ‘Nasik’ Red (Table 4.1). The varietal difference could be due to the inherent genetic variability of the crop and environmental conditions in days to maturity.

The result is in agreement with several authors Lemma Dessalegn and Shimelis Akelilu (2003); Yemane Kahsay *et al.* (2014), Jambo Asfaw and Wassu Muhammad (2015) who reported that cultivars varied significantly from each other with respect to days to maturity.

4.1.2. Leaf number per plant

The analysis of variance revealed that the main effect of intra row spacing was very highly significantly ($P<0.01$) influenced leaf number per plant. Whereas, the main effects of variety and the interaction effect of the two factors were not significantly ($P>0.05$) influenced leaf number per plant (Appendix Table 2).

The maximum number of leaves per plant (11) was obtained at the lower planting density of 10 cm intra row spacing and minimum number of leaves per plant (9) was found at the higher planting density of 4 cm intra row spacing (Table 4.1).

The results of the present study are in agreement with the results of several authors Guesh Tekle (2015); Kiros Gebretsadik (2016) reported that increased plant spacing highly increased onion leaf number per plant and the highest leaf number is produced at wider intra row spacing. Consistent with the results of the present study, several authors Nigullie and Biawas (2017); Habtamu Tegen *et al.*, (2016); Kiros Gebretsadik and Nigussie Dechassa (2018) showed that plants grown at wider spacing produced more leaf number than at closer intra-row spacing. The increase in leaf number along wider intra-row spacing than closer intra-row spacing might be due to less competition of onion plants for growth factors and abundant utilization of resources which accelerate leaf initiation.

4.1.3. Plant height

The analysis of variance revealed that the main effect of intra row spacing had very highly significantly ($P<0.01$) influenced plant height. Whereas, the main effects of variety and their interaction effect had not significantly ($P>0.05$) influenced plant height (Appendix Table 3).

Plant height was highly influenced by spacing such that plant height increased when the spacing of the plant increases. The highest plant height (55.76 cm) was obtained from plants spaced at 10 cm intra row spacing followed by 8 cm spacing (53.62 cm) while the lowest plant height (48.28 cm) was recorded from 4 cm intra row spacing (Table 4.1). The tallest plant height recorded at wider spacing may be due to the availability of free access of environmental resources (water, nutrient and light intensity) for the plants in the wider spacing.

Rahel Demisie (2018), also indicated that the intra-row spacing had significant effect on the plant height and as spacing increased from 7 to 13 cm, the plant height also increased from 58.79 cm to 64 cm height. The result is also in agreement with the findings of Weldemariam Seifu *et al.*, (2015) who reported that the highest plant height was recorded at wider spacing whereas shortest plant height corresponds to the closest plant spacing. The reduction in plant height at higher plant density (narrow spacing) might be attributed to the possible competition for soil moisture and nutrients. Khan *et al.* (2002), also reported that due to higher competition amongst the lowest plant spacing, it produce least response for plant height in onion.

4.1.4. Leaf length

The analysis of variance revealed that the main effect of intra row spacing was very highly significantly ($P<0.01$) influenced leaf length. Whereas, the main effects of variety and their interaction effect with intra row spacing had not significantly ($P>0.05$) influenced leaf length (Appendix Table 4).

Intra row spacing at 10 cm obtained the longest leaf length (50.86cm) and the shortest (43.72cm) was recorded at the narrow 4 cm intra row spacing (Table 4.1). This might be due to the availability of more nutrient and moisture at wider intra-row spacing whereas the closest intra-row spacing leads to strong competition for growth factors such as nutrient and moisture there by cause shorter leaf length.

The result is in agreement with the findings of Jilani *et al.* (2010), who reported that maximum leaf length (43.68 cm) was recorded in plants spaced at 20 cm. whereas shortest leaf length (40.53 cm) was observed in plants, with the closer plant spacing of 10 cm.

Similarly, Sara Belay *et al*., (2015) reported that the leaf length of onion increased with the increasing intra row spacing. Various researchers obtained consistent results with the present study, the wider the spacing the higher leaf length of onion (Guesh Tekel 2015; Kiros Gebretsadik, 2016).

4.1.5. Percentage of bolters per plot

The analysis of variance revealed that the interaction effect of intra-row spacing and variety on days to maturity was not significant. Intra-row spacing and variety significantly affected percentage of bolters ($p<0.01$ and $p<0.01$) respectively (Appendix Table 5).

Increasing intra row spacing from 4 cm to 10 cm increased bolting percentages. The highest bolters percentage of produces (6.11 %) at 10 cm intra row spacing. and the minimum percentage of bolters (2.65%) at 4 cm intra row spacing (Table 4.1).This might be due to the less competition for more nutrients and other resources at wider spacing, which contribute to luxurious growth leading to flower stalk initiation and development. In agreement with the current finding, Mekdes Ataklt (2012) reported that highest bolters percentage was recorded at wider spacing whereas the lowest percentage of bolters corresponds to the closest plant spacing. Bolting may vary due to genetic factors and changes in temperature affecting the growth, relative length of day and night, spacing, and seedling size Salunkhe, (1998).

Regarding variety the highest percentage of bolters (5.22%) was recorded on Bombay red variety and the low percentage of bolters (3.51%) was recorded on Nafis red variety (Table 4.1). Khalid (2009), also observed variety variation in time of inflorescence initiation in two onion cultivars. The results are in conformity with the findings of Walle Tegbew *et al.,* (2018), who reported that the highest bolting percentage was recorded from “Bombay Red” variety.

Table.4.1: Effect of intra-row spacing and variety on days to maturity, leaf number per plant, plant height, and leaf length and % bolters percentage of onion

Treatment	DTM (days)	LNPP (cm)	PH (cm)	LL (cm)	BOL (%)
Intra spacing					
4	94.11^{bc}	8.8^{c}	48.28^{c}	43.72^{c}	2.65^{c}
6	97.33^{bc}	9.4^{bc}	50.83^{bc}	46.16^{bc}	3.54^{bc}
8	102.33^{ab}	9.9^{ab}	53.62^{ab}	48.50^{ab}	4.36^{b}
10	107.44^{a}	10.63^{a}	55.76^{a}	50.86^{a}	6.11^{a}
P- value	***	***	***	**	***
LSD (5%)	5.22	0.76	3.4	3.3	1.03
Variety					
Bombay Red	93.00^{a}	10.18^{a}	51.97^{a}	46.59^{a}	5.22^{a}
Nasik Red	101.75^{b}	9.33^{b}	51.45^{a}	47.03^{a}	3.77^{b}
Nafis Red	106.^{b}	9.54^{ab}	52.9^{a}	48.31^{a}	3.51^{b}
P- value	***	Ns	Ns	Ns	**
LSD (5%)	4.51	0.66	2.96	2.86	0.89
CV (%)	5.31	8.12	6.74	7.18	25.4

Where; *** = very highly significant at P<0.001; ** = highly significant at P<0.01; * = significant at P<0.05; Ns= Non-significant. Means within a column followed by the same letter(s) are not significantly different at p<5%. CV = coefficient of variation; and LSD = Least Significant Difference. DTM = Days to maturity, LNPP= Leaf number per plant, PH= Plant height, LL= Leaf length, BOL= Bolter percentage.

4.2. Yield and Yield components

4.2.1. Bulb length

The analysis of variance showed that bulb length was very highly significantly (P<0.01) influenced by the main effects of intra row spacing and variety. However, their interaction effect did not significantly influence on bulb length (Appendix Table 6). Spacing at 10 cm showed the highest bulb length (5.39 cm) followed by 8 cm (5.18cm) and 6 cm (4.95 cm) while the lowest was recorded from 4 cm (4.82cm) plant spacing. There was no substantial variation between plants grown in bulb length at 4cm and 6 cm intra row spacing (Table 4.2).

Bulb length increased as intra-row spacing increased. This could be attributed to the adequate availability of growth resources at a wider spacing that allows the bulbs to have more assimilates available for storage. These results are in line with the reports of Asres Derejew *et al.* (2017), who found higher bulb length (6.02 cm) from planted grown in wider spacing of (15 cm) and the smaller bulb length (5.48 cm) was obtained from closer spacing (7.5 cm) spacing. In agreement to current finding several researchers Hyder *et al.,* (2007); Hosmani *et al.,* (2010); Yemane Kahsay *et al.,* (2013); Rahel Demisie (2018) also found that increased of intra row spacing bulb length are increased as intra-spacing increased.

Nasik red provided the highest bulb length (5.23cm) recorded than Bombay and Nafis red variety (5.15cm, 4.88cm respectively). The difference in bulb length among varieties may be due to their genetic variability. These results are in line with the reports of Wubetie Adnew *et al.,* (2022) who reported that the longest bulb lengths were observed from Nasik red (4.41 cm) than Robat (4.13 cm) variety, respectively.

4.2.2. Bulb diameters

The analysis of variance revealed that bulb diameters was highly significantly (P<0.01) influenced by the main effects of intra row spacing and variety. However, their interaction effect did not significantly influence bulb diameters of onion (Appendix Table 7).

The largest bulb diameter (5.33 cm) is found in onion plants planted at 10cm distance between plants, followed by plants planted at 8 cm between plants (5.03 cm). Plants separated by 4 cm intra-row spacing provided the lowest bulb diameter (4.41 cm). There was no substantial variation between plants grown in bulb diameters at 4 and 6 cm (Table 4.2).

The increased in bulb diameter at wider plant spacing could be probably attributed to more nutrient, space, and moisture availability and resulting in enlargement of their bulb size. Similarly, high plant density implies closer spacing and ultimate reduction in space available per plant. These results are in line with the reports of Rahel Demisie (2018), who recorded the highest bulb diameter (5.63 cm) when onion plants were spaced at 13 cm intra-row spacing followed by 10 cm intra-row spacing (5.50 cm). Similar to the results of the present study, several researchers Nigullie and Biawas *et al.*, (2017); Kitila Chala *et al.,* (2021) recorded that wider intra row spacing recorded highest bulb diameter.

Regarding to the performance of the variety Bombay red was recorded the maximum bulb diameter (5.26 cm). The minimum bulb diameter was recorded Nafis and Nasik red variety (4.85cm, 4.50cm respectively) (Table4.2).The difference in bulb diameter among variety might be due to their genetic variability and environmental conditions. These results are in line with the reports of Dessie Getahun *et al.* (2020), who reported that the largest bulb diameter was recorded form variety Bombay Red than Nasik red variety at Fogera district. Similarly, Awoke Ali *et al.* (2021) indicted that the wider bulb diameter was measured from variety Bombay Red (5.67 cm) while the narrow bulb diameter was obtained from variety Adama Red (5.18cm) followed by variety Melkam (5.32 cm). The results are also consistent with the finding of several researchers Akoun (2005); Nigullie and Biawas *et al.*, (2017); Kitila Chala *et al.*, (2021) where wider intra row spacing recorded highest bulb diameter.

4.2.3. Bulb shape index

The analysis of variance showed that bulb shape index was highly significantly ($p<0.01$) influenced by the main effects of variety and significantly by intra row spacing ($p<.0.05$). However the interaction effect did not significantly ($p<.0.05$) influence bulb shape index (Appendix Table 8).

The lowest bulb shape index was recorded at wide intra row spacing 10 cm (1.01) while the highest bulb shape index was obtained at narrow spacing 4 cm-8 cm (1.09) (Table 4.2). As the bulb shape index become higher, it showed the presence of longer bulb length which result in more cylindrical/oval shape bulbs. The results are also in consistent with the findings of Grant and Carter (2010) who pointed out that increasing plant density of onion from 50 to 100 plants per square meter increased the percentage of bulb shape index from 7.9 to 15.3%.

Nasik red variety produced the highest bulb shape index (1.12%). Bombay red which produced lower bulb shape index (0.98%) (Table.4.2).The variation between varieties in bulb shape index is due to a genetic factor and environmental condition. Similarly, Kimani *et al.* (1993), reported bulb shape difference among onion cultivars was affected by environmental conditions. These results are in line with the reports of Mekdes Ataklt (2012) who documented that '*Bombay*' Red variety produced the minimum bulb shape index (1.10) as compared to *'Nasik'* Red which produced higher.

4.2.4. Average bulb weight

Results from the analysis of variance indicated that the main effects of variety and intra row spacing respectively had highly significantly ($p<0.01$) and very highly significantly ($p<0.001$) affected average bulb weight respectively. However their interaction effect did not significantly ($P>0.05$) influence the average bulb weight of onion (Appendix Table 9).

Highest bulb weight (75.22 g) was recorded in plants spaced at 10 cm, followed by 8 cm spacing (63 g), while the lowest average bulb weight of (43.05g) was recorded from the closest intra row spacing of 4 cm (Table 4.2).

The result indicted that densely populated plants produced lower bulb weight as compared to thinly populated plants likely due to competition associated with closely spaced plants that resulted in lower bulb weight per plant.

Similar results were reported by Nigullie and Biawas (2017) and Yemane Kahsay *et al.,* (2013) that wider plant spacing in onion, resulted in heavier bulb weight. This result also confirmed by Weldemariam Seifu *et al.* (2015), who reported that increase of average bulb weight from 41.97 to 92.2g as intra-row spacing increased from 10 to 15 cm.

Among the variety 'Bombay' Red produced much heavier bulb weight (66.58g) as compared to Nafis Red and 'Nasik' Red which produced bulbs weight of (56.29 g, 51.04g respectively) (Table 4.2). Average bulb weight among variety was may be due to their genetic variability as well as wider spacing provides more area, light and less nutrient competition among plants, which increase weight of bulb in onion. Difference in average bulb weight among variety was may be due to their genetic variability and environmental conditions.

Similarity, Gezahegn Fikre *et al.,* (2021) reported higher fresh bulb weights of (126.4 g and 121.8 g) from variety Bombay red and Nafis respectively. And the lowest fresh bulb weight of (102.8 g) was observed from Adama red variety. This result is also inconformity with several researchers Hosmani *et al.,* (2010); Yemane Kahsay *et al.,* (2013) who stated that the increase in intra row spacing increased, average bulb weight of the onion plants.

Table 3.2: Effect of intra-row spacing and variety on bulb length, bulb diameters, bulb shape index, and average bulb weight

Treatment	BL (cm)	BD (cm)	BSI	ABW (g)
intra row spacing				
4	4.82[b]	4.41[bc]	1.09[a]	43.05[c]
6	4.95[b]	4.70[bc]	1.05[a]	50.61[c]
8	5.18[ab]	5.03[ab]	1.03[ab]	63.00[b]
10	5.39[a]	5.33[a]	1.01[b]	75.22[a]
P-value	***	**	*	***
LSD (5%)	0.28	0.50	0.16	10.12
Variety				
Bombay Red	5.15[a]	5.26[a]	0.98[a]	66.58[a]
Nasik Red	5.44[b]	4.85[a]	1.12[a]	51.04[b]
Nafis Red	4.75[c]	4.50[ab]	1.05[ab]	56.29[b]
P-value	*	**	**	**
LSD (5%)	0.24	0.43	0.14	8.76
CV (%)	5.58	10.62	14.77	17.94

Where; *** = very highly significant at P<0.001; ** = highly significant at P<0.01; * = significant at P<0.05; Ns= Non-significant. Means within a column followed by the same letter(s) are not significantly different at p<5%. CV = coefficient of variation; and LSD = Least Significant Difference. BL= Bulb length, BD=Bulb diameters, BSI= Bulb shape index, ABW= Average bulb weight.

4.2.8. Marketable bulb yield

The analysis of variance showed that the main effects of intra row spacing and variety had very highly significantly ($P<0.01$) influenced the marketable bulb yield of onion. In contrast, their interaction effects had not influenced this parameter (Appendix Table 10).

As an intra-row spacing level increased from 4 to 10 cm the marketable bulb yield decreased. The highest marketable bulb yield (33.18 tons ha^{-1}) was obtained at narrow intra row spacing (4 cm) while wider intra-row spacing (10 cm) gave the lowest marketable bulb yield (19.98 tons ha^{-1}) (Table 4.3).

The highest marketable bulb yield in narrow intra-row spacing might be due to high plant population thus, plants produced more bulb yields and leads to highest number of bulbs with marketable bulb size. Although plant height, number of leaves per plant and leaf length increased with increasing spacing in the present study, higher number of plants per unit area with enough supply of different agronomic practices increased marketable bulb yield.

Simon *et al.* (2014) also indicted that the highest marketable bulb yield (38.93 tons ha^{-1}) was obtained from plants grown at 7 cm intra-row spacing while an intra-row spacing 13 cm showed the lowest marketable bulb yield (25.21 tons ha^{-1}).

Bombay Red variety recorded the highest marketable bulb yield (28.18tons ha^{-1}) followed by variety Nasik Red (26.05tons ha^{-1}) and the lower marketable bulb yield (25.08tons ha^{-1}) was obtained from variety Nafis Red (Table 4.3). The differences between onion varieties may be due to their ability to produce bulbs under different agricultural climatic conditions and genetic makeup. Mekdes Ataklt (2012) also reported that the highest marketable bulb yield (32.90tons ha^{-1}) was recorded from variety 'Bombay' Red and the lowest marketable bulb yield (30.35tons ha^{-1}) was obtained from the variety 'Nasik' Red. This result is in line with the reports of several authors Nigussie Dechassa (2018); Hailu Dinka *et al.,* (2015); Rahel Demisie and Kassaye Tolessa (2018) who reported that intra row spacing increased the marketable bulb yield decreased.

4.2.9. Unmarketable bulb yield

Results from the analysis of variance indicated that the main effects of intra row spacing and variety had very significantly ($P<0.01$) influenced the unmarketable bulb yield of onion. However their interaction effect did not significantly ($P<0.01$) influenced the unmarketable bulb yield of onion (Appendix Table 11).

The maximum amount of unmarketable bulb yield (5.20 %) was recorded at 4 cm intra row spacing. while the lower amount of unmarketable bulb yield (4.76%) was attained at 10 cm intra row spacing (Table 4.3). The cause of un-marketability especially at narrow spacing is mainly due to small bulb size (<20g).The highest unmarketable yield in a narrow spacing may be related to increased competition for growth promoting resources and lack of nutrient for the growth and development of all plants in the stand which has led to a much reduction of big bulbs than wider spacing. Kitila Chala *et al.,* (2021), also mentioned that the highest unmarketable bulb yield of onion was produced by the narrow intra-row spacing.

The results are in conformity with the findings of Derejew Asres *et al.,* (2012), who reported that high unmarketable yield of onion was recorded in closely spaced plants. Similarly, Kiros Gebretsadik and Nigussie Dechassa (2018) reported that with the increase in the intra row spacing unmarketable bulb yield of onion decreased.

The maximum unmarketable bulb yield (5.92%) was attained from variety of Nasik Red followed by Bombay Red variety (5.09). The lowest unmarketable bulb yield (4.13 %) was recorded in the variety Nafis Red (Table 4.3). The differences between onion varieties in unmarketable bulb yield may be related with the adaptability of the onion varieties in study area. Accordingly Nafis red had better adaptability compared with the other two onion varieties in the study area.

In agreement with the present study, Wubetie Adnew *et al.* (2022), also reported that the highest unmarketable bulb yield (1.75 tons ha^{-1}) was obtained from the variety of Nasik red (1.19 tons ha^{-1}) and while the least values were recorded from Robat with (0.79 tons ha^{-1})

4.2.10. Total bulb yield

The analysis of variance showed that the main effects of intra row spacing and variety effects was very highly significantly ($P<0.01$) influenced the total bulb yield onion. However their interaction effect did not significantly ($P<0.01$) influenced the total bulb yield onion (Appendix Table 12).

As intra row spacing increased from 4 cm to 10cm the total bulb yield productivity decreased. The highest total bulb yield (34.99tons ha^{-1}) was recorded at 4 cm intra row spacing. An intra-row spacing 10 cm showed the lowest total bulb yield (21.04tons ha^{-1}) (Table 4.3).

Differences in the bulb productivity may be related with difference in genotypes, climate, cultural practices and their interactions. The increased total bulb yield by high plant population might be due to increased plant stand and consequently, a higher number of bulbs produced per unit area. However, the weight of bulbs reduced due to higher competition among plants for growth factors. This might be at wider spacing the number of plants per hectare reduced, thus causing a reduction in yield and vice versa. The results are in conformity with the findings of Yemane Kahsay *et al.,* (2013) who reported that the highest total bulb yields were achieved at 5 and 7.5 cm intra-row spacing, respectively as compared to the 10 cm intra-row spacing.

The maximum total yield of bulb (29.69tons ha^{-1}) was attained from variety of Bombay red followed by Nasik (27.69 tons ha^{-1}). The lowest total bulb yield (26.16tons ha^{-1}) was recorded in the variety Nafis red. However, it was not statistically different from that recorded by 'Nasik' Red (Table 4.3).

Similarly observation was made by Mekdes Ataklt (2012), who reported that the highest total bulb yield (35.22 tons ha^{-1}) was recorded from variety 'Bombay' Red and the lowest total bulb yield of (19.50 tons ha^{-1}) was obtained from the variety 'Nasik' Red. This finding is agreed with the finding of Jilani *et al*. (2009) who suggested that varieties could have different yield potential in different agro ecologies due to their genetic potential and genotype by environment interaction effect.

The results are in conformity with the findings Asres Derejew *et al.,* (2017); Nigullie and Biawas (2017) who stated that increasing intra row spacing more than 5cm decreases the total bulb yield of onion.

4.2.11. Harvest index

The analysis of variance indicated that the main effect of variety and intra row spacing had very highly significantly ($P < 0.01$) influenced the harvest index of onion. However the interaction effect did not influence significantly the harvest index of onion (Appendix Table 13).

Intra row spacing of 4 cm showed the highest harvesting index (94.28%) followed by 6 cm and 8 cm intra row spacing (92.42%, 90.51% respectively). The lower harvesting index recorded at 10 cm intra row spacing (88.04%) (Table 4.3). The lowest harvest index at the wider spacing for 'Nafis' Red might be due to the production of more vegetative parts including flower stalks, which compute assimilate than the economically important parts or bulb. This finding is agreed with the finding of several researchers Mekdes Ataklt (2012); Yemane *et al*., (2013) for onion, and Asers Derejew *et al*., (2012), for shallot who reported that wider intra-row spacing resulted in lower harvest indices.

Highest harvest index (93.99%) was recorded on 'Bombay' Red Variety. The lowest harvest index (89.90%) was recorded by 'Nafis' Red variety. However, it was on par with that of Naisk Red (90.27%) (Table 4.3).

Similarly, Walle Tegbew *et al. (*2018), stated that Bombay Red" produced higher harvest index which was about 9% more than that of "Adama Red. The authors further stated that early maturing plants generally achieve higher values of harvest index, which is also true for the Bombay Red cultivar.

The results are in conformity with the findings Walle Tegbew *et al. (*2018); Dantuma, G. and R.Thompson, (1983), who reported early maturing plants generally achieve higher values of harvest index, which is also true for the Bombay Red cultivar.

Table.4.3: effect of intra row spacing on marketable bulb yield, unmarketable bulb yield, total bulb yield and harvest index

Treatment	MY (t/ha)	UMY (%)	TY (t/ha)	HI (%)
intra row spacing				
4	33.18[a]	5.20[a]	34.99[a]	94.28[a]
6	28.72[b]	5.06[b]	30.25[b]	92.42[ab]
8	23.87[c]	4.90[c]	25.10[c]	90.51[b]
10	19.98[d]	4.76[d]	21.04[d]	88.04[c]
P-value	***	***	***	***
LSD (5%)	0.85	0.13	0.88	2.23
Variety				
Bombay Red	28.18[a]	5.09[b]	29.69[a]	93.99[a]
Nasik Red	26.06[b]	5.92[a]	27.69[b]	90.27[b]
Nafis Red	25.08[c]	4.13[c]	16.16[c]	89.90[b]
P-value	***	***	***	***
LSD (5%)	0.73	0.15	0.76	1.93
CV (%)	3.27	12.27	3.24	2.5

Where; *** = very highly significant at P<0.001; ** = highly significant at P<0.01; * = significant at P<0.05; Ns= Non-significant. Means within a column followed by the same letter(s) are not significantly different at p<5%. CV = coefficient of variation; and LSD = Least Significant Difference. MY= Marketable bulb yield, UMY= Unmarketable bulb yield, TY= Total bulb yield, HI= Harvest index.

4.4. Economic Analysis of Onion as Affected by Intra row Spacing and Variety.

4.4.1. Partial budget analysis

Partial budgeting is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. According to CIMMYT (1988) the partial budget analysis includes the total variable costs and net benefits of each treatment. The gross benefit of the treatments was calculated using the adjusted marketable yield and the field price of the crops while the net benefit was calculated by subtracting variable costs from the gross benefit of each treatment. In the present study, the field price of onion bulb was taken as 29.00 Birr kg^{-1} for all varieties and marketable bulb sizes. The average labor and seed costs were also variable for all treatments based on spacing. Moreover the marketable onion bulb yield was adjusted by 10% to make comparable to yields of farmers.

According to the procedures described by CIMMYT (1988), the highest net benefit 621887.53 ETB Birr ha^{-1} was obtained from plants treated with the treatment combination of Bombay Red cultivar and 4cm intra row spacing. On the other hand, the second highest net benefit was recorded from treatment combination of Nafis red variety and 4 cm intra row spacing (Table 4.5.).

Table.4.5: Economical analysis for marketable yield of onion as affected by intra-row spacing and variety

Variety	Spacing (cm)	MY (tha-1)	Adj.MY (tha-1)	GFB (ETB ha^{-1})	SC (ETB)	LC (ETB)	TVC (ETB)	NB (ETB)
BR	10	18.981	16.60829	481640.41	3000	150000	153000	328640.4
NS	10	18.055	16.2495	471235.5	3300	150000	153300	317935.5
NF	10	18.20867	16.3878	475246.2	3600	150000	153600	321646.2
BR	8	20.98733	18.8886	547769.4	4500	170000	174500	373269.4
NS	8	21.296	19.1664	555825.6	4950	170000	174950	380875.6
NF	8	20.13933	18.9254	548836.6	5400	170000	175400	373436.6
BR	6	27.00533	24.3048	704839.2	6000	200000	206000	498839.2
NS	6	27.004	24.3036	704804.4	6600	200000	206600	498204.4
NF	6	27.31433	24.5829	712904.1	7200	200000	207200	505704.1
BR	4	33.02433	29.7219	861935.1	8500	220000	228500	633435.1
NS	4	31.32667	28.194	817626	9350	220000	229350	588276
NF	4	31.63533	28.4718	825682.2	10200	220000	230200	595482.2

Note; Note: NS= Nasik red; NF=Nafis red; BR Bombay red; MY=Marketable yield; AMY= Adjustable marketable yield; SC= Seed cost; LC= Labor cost; TVC= Total variable cost; NB= Net benefit.

Table.4.6: Dominance analysis for marketable yield of onion as affected by intra-row spacing and variety

Treatments		MY	Adj.MY	TVC	NB	Dominance
Variety	Spacing (cm)	(tha-1)	(tha-1)	(ETB)	(ETB)	
BR	10	18.981	16.60829	153000	328640.4	
NS	10	18.055	16.2495	153300	317935.5	D
NF	10	18.20867	16.3878	153600	321646.2	D
BR	8	20.98733	18.8886	174500	373269.4	
NS	8	21.296	19.1664	174950	380875.6	
NF	8	20.13933	18.9254	175400	373436.6	D
BR	6	27.00533	24.3048	206000	498839.2	
NS	6	27.004	24.3036	206600	498204.4	D
NF	6	27.31433	24.5829	207200	505704.1	
BR	4	33.02433	29.7219	228500	633435.1	
NS	4	31.32667	28.194	229350	588276	D
NF	4	31.63533	28.4718	230200	595482.2	D

Note: NS= Nasik red; NF=Nafis red; BR Bombay red; MY=Marketable yield; AMY= Adjustable marketable yield; TVC= Total variable cost; NB= Net benefit; DO= dominances

4.4.2. Marginal rate of return

According to CIMMYT (1988), any treatments that have net benefits less or equal to the previous treatment is dominated which should be removed from further analysis (Table 4.7). Accordingly, all treatment combinations resulted acceptable marginal rate of return (>100%), plants, which were planted at 4 cm intra row spacing and Bombay red variety recorded the highest marginal rate of return (4815.24%) as indicated by (Table 4.7).

Table.4.7: Marginal rate of return (MRR) of marketable onion yield as affected by intra-row spacing and variety

Treatments		**TVC**	**NB**	**MRR (%)**	**Rank**
Variety	Spacing (cm)	(ETB)	(ETB)		
BR	10	153000	328640.4	0	
NS	10	153300	317935.5		
NF	10	153600	321646.2		
BR	8	174500	373269.4	207.58	5
NS	8	174950	380875.6	490.27	3
NF	8	175400	373436.6		
BR	6	206000	498839.2	379.91	4
NS	6	206600	498204.4		
NF	6	207200	505704.1	572.08	2
BR	4	228500	633435.1	599.86	1
NS	4	229350	588276		
NF	4	230200	595482.2		

Note; NS= Nasik red; NF=Nafis red; BR= Bombay red; TVC= Total variable cost; NB= Net benefit; MMR= Marginal rate of return

Chapter 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The selection of the best onion varieties with the appropriate intra row spacing is essential factor to improve the growth and bulb yield of onions. The results of the present study indicated that the varieties and intra row spacing highly significantly influenced growth and yield parameters of onion. However, the interaction effect had not significantly affected tested parameters of onion. Based on this result the varieties and the intra row spacing had not interacted to affect the growth and yield components of onion. This indicated that the effect of one factor is not dependent on the other factor. So that, the response of the onion varieties for the different intra rowing spacing had not significant variation

According to the present study, Bombay red variety performed well in the tested growth and yield parameters of onion as compared to Nasik and Nafis red variety, where Bombay variety produced the highest marketable bulb yield. However, Nasik red variety recorded the highest bulb length although higher unmarketable bulb yields of onion. With decreasing intra row spacing, the tested parameters of onion marketable bulb yield, unmarketable bulb yield and total bulb yield also increased. Accordingly, growing the tested onion varieties in optimum intra row spacing (4cm) was recorded the highest marketable and total bulb yield of onion.

Generally, the highest marketable bulb yield and total bulb yield of onion was obtained from Bombay Red variety at 4 cm intra row spacing. Based on the partial budget analysis, the highest net benefit (633435.1Birr ha^{-1}) and the highest marginal rate of return (599.86%) were obtained from the combination of Bombay variety with 4 cm intra row spacing ha^{-1}.

5.2. Recommendation

Based on the results of the present study, Bombay Red variety at 4 cm intra row spacing 33.18 ha^{-1} can be recommended for economical production of onion in the study area and similar agro ecologies. *Nasik'* Red even if it produce low bulb yield (26.06 ha^{-1}) could be superior as potential for

highest bulb length and bulb shape index. However, as the results are limited to one season and a single location, future research work in multiple locations and seasons are also recommended for sustainable recommendation

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APPENDIXES

Appendix 1 Analysis of variance for days to maturity

Source	DF	Mean Square	F Value	Pr > F	P- value
Rep	2	0.1057	6.52	0.0132	*
VAR	2	538.861111	18.93	<.0001	***
SP	3	306.842593	10.78	0.0001	***
VAR*SP	6	2.009259	0.07	0.9983	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 2 Analysis of variance for leaf number per plant

Source	DF	Mean Square	F Value	Pr > F	P- value
Rep	2	0.235	3.28	0.021	*
VAR	2	2.35527778	3.81	0.0666	*
SP	3	5.41138889	8.75	0.0004	***
VAR*SP	6	0.11861111	0.19	0.9762	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 3 Analysis of variance for plant height

Source	DF	Mean Square	F Value	Pr > F	P- value
Rep	2	0.4581	5.38	0.022	*
VAR	2	7.0352778	0.57	0.5734	Ns
SP	3	95.6625926	7.74	0.0009	***
VAR*SP	6	7.0689815	0.57	0.7486	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 4 Analysis of variances for leaf length

Source	DF	Mean Square	F Value	Pr > F	P- value
Rep	2	0.4581	5.38	0.032	*
VAR	2	9.6352778	0.83	0.4466	Ns
SP	3	84.7358333	7.33	0.0012	**
VAR*SP	6	5.5097222	0.48	0.8188	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 5 Analysis of variances for bolters percentage

Source	**DF**	**Mean Square**	**F Value**	**Pr > F**	**P- value**
Rep	**2**	0.2075	5.67	0.0132	*
VAR	2	10.231975	9.1	0.0011	**
SP	3	19.59307407	17.43	<.0001	***
VAR*SP	6	1.18999352	1.06	0.4139	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 6 Analysis of variances for bulb length

Source	**DF**	**Mean Square**	**F Value**	**Pr > F**	**P - value**
Rep	2	0.22443611	2.78	0.0839	Ns
VAR	2	0.40423611	5.01	0.0162	*
SP	3	0.56604722	7.01	0.0018	**
VAR*SP	6	0.04295833	0.53	0.7781	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 7 Analysis of variances for bulb diameters

Source	DF	Mean Square	F Value	Pr > F	P - value
Rep	2	1.20386944	4.49	0.0231	*
VAR	2	1.76361944	6.58	0.0058	**
SP	3	1.42348519	5.31	0.0066	**
VAR*SP	6	0.07804907	0.29	0.9347	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 8 Analysis of variances for bulb shape index

Source	DF	Mean square	F – value	Pr > F	P - value
VAR	2	0.19121111	6.43	0.0058	**
SP	3	0.11368426	3.83	0.0227	*
VAR*SP	6	0.04673704	1.57	0.1983	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 9 Analysis of variances for average bulb weight

Source	DF	Mean Square	F Value	Pr > F	P-value
Rep	2	0.1248	5.71	0.0166	*
VAR	2	750.049	6.93	0.0042	**
SP	3	1798.6	16.62	<.0001	***
VAR*SP	6	215.039	1.99	0.1074	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 10 Analysis of variances for marketable bulb yield

Source	DF	Mean Square	F Value	Pr > F	P- value
Rep	2	2.3805781	3.18	0.0613	Ns
VAR	2	30.3077048	40.46	<.0001	***
SP	3	297.0566771	396.57	<.0001	***
VAR*SP	6	3.065355	4.09	0.066	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 11 Analysis of variances for unmarketable bulb yield

Source	DF	Mean Square	F Value	Pr > F	P-value
Rep	2	0.14897558	4.97	0.0166	*
VAR	2	1.03227308	34.42	<.0001	***
SP	3	1.0093433	33.66	<.0001	***
VAR*SP	6	0.00768494	0.26	0.9514	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 12 Analysis of variances for total bulb yield

Source	DF	Mean Square	F Value	Pr > F	P-value
Rep	2	0.19868	7.57	0.0166	*
VAR	2	1.03227	34.42	<.0001	***
SP	3	1.00934	33.66	<.0001	***
VAR*SP	6	0.00768	0.26	0.9514	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom

Appendix 13 Analysis of variances for harvesting index

Source	DF	Mean Square	F Value	Pr > F	P-value
Rep	2	0.23898	8.83	0.0166	*
VAR	2	61.2433	11.59	0.0003	***
SP	3	66.4306	12.58	<.0001	***
VAR*SP	6	3.8537	0.73	0.6304	Ns

Where; *** = very highly significant at P<0.001; * = significant at P<0.05; Ns = non-significant and Df = Degree of freedom



Appendix figure 1seedling preparations on nursery area during 2022 irrigation growth season



Appendix figure 2 planting area preparation and after transplanting during 2021 irrigation growth season




Appendix figure 3 Maturity more than 80 days of phonological maturity growth stage sample

BIOGRAHPICAL SKECTH

Tesfaye Gobezayhu Tayachewu , the author was born on December 19, 1992 GC at Pawi, Metekel zone of Binshagule Gumze region, Ethiopia from his father Ato Gobezayehu Tayachewu and his mother W/ro Bezinash Mulegita . He attended his elementary education at pawi elementary and Junior School and his secondary school education at pawi comprehensive secondary schools. In 2014 GC, he completed his high school education and then joined Deber Tabor University, College of Agricultural and environmental Sciences and graduated in July 2017 GC with B.Sc. Degree in plant Sciences.

In June 2020, he was employed by Ashraf agro industry and worked as agronomist at Bihar Dar edible oil Company. In October 2022, he joined the school of graduate studies of Bihar Dar University College of Agriculture and environmental Sciences to pursue his postgraduate studies leading to Master of Science degree in Horticulture.