



**EFFECT OF DIFFERENT TYPES OF FERTILIZERS ON YIELD AND
YIELD COMPONENTS OF ONION (*Allium cepa* L.) VARIETIES IN
ENEMORE WOREDA OF GURAGE ZONE, ETHIOPIA**

MSc. THESIS

BY

MESFIN WONDIMU HABTE

WOLKITE UNIVERSITY, WOLKITE, ETHIOPIA

MARCH 2022

WOLKITE UNIVERSITY
SCHOOL OF GRADUATE STUDIES
EFFECT OF DIFFERENT TYPES OF FERTILIZERS ON YIELD
AND YIELD COMPONENTS OF ONION (*Allium cepa* L.)
VARIETIES IN ENEMORE WOREDA OF GURAGE ZONE,
ETHIOPIA

MSc. THESIS

MESFIN WONDIMU HABTE

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF
WOLKITE UNIVERSITY IN FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE
(MSc.) IN HORTICULTURE

WOLKITE, ETHIOPIA

MARCH 2022

ACKNOWLEDGMENTS

Firstly and foremost, I would like to thank the Almighty God for giving me the strength to go through all the challenging times. Secondly, I would like to passionately thank my major advisor, Dr. Zenebe Woldu Adane for his tireless supervision, constructive comments and suggestions as well as overall advice, without which the successful completion of this thesis would have been unthinkable. Similarly, I wish to express my sincere gratitude to my co-advisor, Mr. Solomon Kebebew for his constructive suggestions and comments provided during my research work and final write up of the thesis. Thirdly, I would like to extend my heartfelt gratefulness to my beloved wife, Mrs. Mekdes Assefa Bogebo, for her unlimited and all rounded support and encouragement throughout my course and research work as well as beyond. Finally, I wish to express my heartfelt thanks and appreciation to Mr. Amare Zerga, Mr. Nigussie Senbeto, Mr. Habte Wedema and Mr. Feki Denka for their unreserved assistance towards the successful completion of my study.

TABLE OF CONTENTS

| Contents | pages |
|-------------------------------------------------------------------------|-------|
| ACKNOWLEDGMENTS | ii |
| LIST OF FIGURES | viii |
| LIST OF ABBREVIATIONS AND ACRONYMS | ix |
| LIST OF APPENDIX TABLES..... | x |
| LIST OF APPENDIX PLATES (PHOTOS)..... | xi |
| ABSTRACT | xii |
| 1. INTRODUCTION | 1 |
| 1.1. Background and Justification | 1 |
| 1.2. Objectives of the Study | 6 |
| 1.2.1. General objective | 6 |
| 1.2.2. Specific objectives | 6 |
| 2. LITERATURE REVIEW | 7 |
| 2.1. Botany and Origin of Onion | 7 |
| 2.2 Distribution and Importance of Onion | 8 |
| 2.3. Onion (<i>Allium cepa</i> L.)Production Status at the World | 9 |
| 2.4. Ecological Requirement of Onion | 10 |
| 2.5. Importance and Production Status of Onion in Ethiopia..... | 11 |
| 2.6. Response of Onion to Inorganic Fertilizers..... | 13 |
| 2.6.1. Response of onion to nitrogen fertilizers | 13 |
| 2.6.2. Response of onion to phosphorus fertilizers..... | 15 |
| 2.6.3 Response of onion to sulfur fertilizers | 17 |
| 2.6.4. Response of onion to Boron fertilizers | 19 |
| 2.6.5. Response of onion to Zinc fertilizers | 20 |
| 3. MATERIALS AND METHODS | 21 |
| 3.1. Description of the study area..... | 21 |
| 3.2. Description of the experimental materials..... | 22 |
| 3.2.1. Planting Materials | 22 |
| 3.2.2. Fertilizers materials..... | 22 |

| | |
|----------------------------------------------------------------------------------------------------|----|
| 3.3. Treatment and Eexperimental Design | 22 |
| 3.4. Treatment Combinations | 23 |
| 3.5. Experimental procedure..... | 25 |
| 3.6. Data Collection | 26 |
| 3.6.1. Soil sampling and Analysis..... | 26 |
| 3.6.2. Growth parameters..... | 27 |
| 3.6.3. Yield and Yield Componente parameters of onion..... | 28 |
| 3.6.4. Economic Analysis (Partial Budget Analysis)..... | 29 |
| 3.7. Statistical Analysis | 29 |
| 4. RESULTS AND DISCUSSION..... | 30 |
| 4.1. Soil Physicochemical Properties of the Experimental Site | 30 |
| 4.1.1. Soil Physical Properties | 30 |
| 4.1.2. Soil Chemical Properties..... | 30 |
| 4.2. Phonological and growth Parameters of Onion..... | 32 |
| 4.2.1. Days to 80% of physiological maturity | 32 |
| 4.2.2. Average plant height (cm) | 34 |
| 4.2.3. Average leaf length (cm) | 37 |
| 4.2.4. Average leaf number..... | 38 |
| 4.3. Yield and Yield Components of onion..... | 40 |
| 4.3.1. Average bulb diameter(cm) | 40 |
| 4.3.2. Average fresh bulb weight(g) | 41 |
| 4.3.3. Average bulb dry weight(g)..... | 42 |
| 4.3.4. Marketable bulb yield($t\ ha^{-1}$) | 44 |
| 4.3.5. Unmarketable bulb yield($t\ ha^{-1}$)..... | 46 |
| 4.3.6. Total bulb yield ($t\ ha^{-1}$)..... | 47 |
| 4.4. Correlation Analysis on Growth, Yield Component and Yield of onion | 50 |
| 4.5. Economic Analysis of onion as influenced by different types of fertilizer and Varieties | 52 |
| 4.5.1. Partial budget analysis | 52 |
| 4.5.2. Marginal rate of return..... | 54 |

| | |
|-----------------------------------------|----|
| 5. CONCLUSION AND RECCOMENDATIONS | 56 |
| 5.1. Conclusion..... | 56 |
| 5.2. Recommendations | 57 |
| 6. REFERENCES | 58 |
| 7. APPENDIXES..... | 68 |
| 7.1. Appendix Tables..... | 68 |
| 8. BIOGRAPHIC SKETCH | 75 |

LIST OF TABLES

| Table | page |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| 1: Specific characteristics/traits of the nationally released varieties of onion in Ethiopia | Error! Bookmark not defined. |
| 2: Treatment combinations was used for the study area..... | 23 |
| 3: Fertilizer rates used for the experiment..... | 24 |
| 4: Soil physico - chemical properties of the experimental site..... | 32 |
| 5: Main effect of Varieties and different types of fertilizer on days to maturity of onion .. | 34 |
| 6: Main effect of Varieties and different types of fertilizer on plant height of onion | 36 |
| 7: Interaction effects of different types of fertilizer and Varieties on Leaf Length of onion..... | 38 |
| 8: Interaction effects of different types of fertilizer and Varieties on Leaf Number----- ----- | 40 |
| 9: Interaction effects of different types of fertilizer and Varieties on Bulb diameter of onion..... | 41 |
| 10: Interaction effects of different types of fertilizer and Varieties on Average fresh bulb weight of onion..... | 42 |
| 11: Main Effects of different types of fertilizer and Varieties on Bulb dry weight of Onion | 44 |
| 12: Interaction effects of different types of fertilizer and Varieties on Marketable bulb yield of onion..... | 45 |
| 13: The Main effect of Varieties and different types of fertilizer on unmarketable bulb yields of onion----- | 47 |
| 14: Interaction effects of different types of fertilizer and Varieties on Total Marketable Yield of onion..... | 49 |
| 15: Correlation Analysis on Growth, Yield Component and Yield of onion | 51 |
| 16: Partial budget analysis of onion as influenced by different types of fertilizer and Varieties in Enemore during the 2020/2021 irrigation season | 53 |

| | |
|------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Table 17: Dominance analysis of onion as influenced by different types of fertilizer and Varieties in Enemore during the 2020/20201 | 54 |
| 18: Marginal rate of return (MRR) of onion as influenced by different types of fertilizer and Varieties in Enemore during the 2020/20201 | 55 |

LIST OF FIGURES

| Figure | page |
|-----------------------------------------|------|
| 1. Location map of the study area | 21 |

LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|-----------|----------------------------------------------------------|
| ANOVA | Analysis of Variance |
| ATA | Agricultural Transformation Agency |
| Birr | Ethiopian Currency |
| CIMMYT | International Maize and Wheat Improvement Center |
| CSA | Central Statistical Agency |
| CSSE | Crop Science Society of Ethiopia |
| CV | Coefficient of Variation |
| DAP | Di-Ammonium Phosphate |
| EARO | Ethiopian Agricultural Research Organization |
| EIAR | Ethiopian Institute of Agricultural Research |
| Ethio-SIS | Ethiopian Soil Information System |
| FAO | Food and Agricultural Organization of the United Nations |
| FAOSTAT | Food and Agricultural Organization Statistics |
| LSD | Least Significant Difference |
| M.a.s.l | Meters Above Sea Level |
| MoARD | Ministry of Agriculture and Rural Development |
| RCBD | Randomized Complete Block Design |
| SARI | Southern Agricultural Research Institute |
| SAS | Statistical Analysis Software |

LIST OF APPENDIX TABLES

| Appendix table | page |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1: Mean squares from analysis of variance (ANOVA) for days to maturity, plant height, leaf length and number of leaves of onion as influenced by different types of fertilizer and Varieties | 68 |
| 2: Mean squares from analysis of variance (ANOVA) for bulb diameter, average fresh bulb weight and bulb dry weight of onion as influenced by different types of fertilizer and Varieties | 68 |
| 3: Mean squares from analysis of variance (ANOVA) for marketable bulb yield, unmarketable bulb yield and total bulb yield of onion as influenced by different types of fertilizer and Varieties | 69 |
| 4: Partial budget analysis of onion as influenced by different types of fertilizer and Varieties in Enemore | 70 |
| 5: Laboratory analysis results of the soil physicochemical properties of the experimental/study site..... | 71 |

LIST OF APPENDIX PLATES (PHOTOS)

| Appendix plate | page |
|----------------------------------------------------------------------------------------------------------|------|
| 1: Partial view of the experimental area, Enemore Woreda Agric. Office Nursery Site Terhogne Kebele----- | 72 |
| 2: Pre-transplanting land preparation of the experimental area ----- | 73 |
| 3: Mulching of onion seedbeds----- | 73 |
| 4: Post-transplanting management and mid-term evaluation of the experiment ----- | 74 |
| 5: Harvesting and sample grading of onion bulbs----- | 74 |

ABSTRACT

*Onion is one of the most important vegetable crops produced as a condiment for home consumption and income sources in many parts of Ethiopia. However, the productivity of onion is low due to various limiting factors, among which low soil fertility and lack of improved site specific varieties are the major ones. Hence, this study was initiated to evaluate and determine the effects of different types of fertilizers on the yield and yield components of nationally released onion (*Allium cepa* L.) Varieties in Enemore Woreda (district) of Gurage zone. A combination of four fertilizer treatments and four varieties were used. These were: 200kg ha⁻¹NP, 242kg ha⁻¹NPS, 244kg ha⁻¹NPSB and 257kg ha⁻¹NPSZn; and Bombay Red, Nafis, Red Creole and Nasik Red of onion varieties. The experiment was laid out in Randomized Complete Block Design, under factorial arrangement and with three replications. There were a total of 16 treatment combinations and 48 experimental units. Data were collected on various parameters of growth, yield and yield components using standard procedures. The data were analyzed using a SAS software version 9.3. The analysis of variance revealed that the main effect of both the different types of fertilizers and onion varieties influenced plant height, date of maturity and bulb dry weight. However, the unmarketable bulb yield was highly significantly ($p < 0.001$) affected only by varieties. There was also statistically highly significant ($p < 0.001$) interaction effect on leaf length, leaf number, bulb diameter, average fresh weight, marketable bulb yield, and total bulb yield. Accordingly, the treatment combination of 244 kg ha⁻¹ NPSB fertilizer and variety Red Creole recorded the highest plant height (68.25cm), bulb diameter (6.1cm), leaf length(59.9cm), leaf number (13.66), average bulb fresh weight (103.66g), marketable yield (31.64 t ha⁻¹) and total bulb yield(32.25 t ha⁻¹). On the other hand, correlation analysis showed that almost all the tested yield and yield component parameters were highly significantly and positively correlated with the marketable bulb yield of onion. Besides, as revealed by the partial budget analysis, plants supplied with 244 kg ha⁻¹ NPSB and variety Red Creole recorded the highest net benefit if Birr 462412.00 with acceptable Marginal Rate of Return (MRR,3441.7%), which can be recommended for economical production of onion at Enemore Woreda. Nevertheless, since, the study was conducted only for a single season and one location, further research is recommended to be carried out at different seasons of the year and multiple potentially representative locations.*

Keywords: *Blended fertilizers, onion, varieties, yield components, yield*

1. INTRODUCTION

1.1. Background and Justification

Onion (*Allium cepa* L.) is the most widely cultivated species of the genus *Allium*. The crop belongs to the family *Alliaceae* (Hanelt, 1990). Onion is one of the cool season bulb vegetables produced throughout the world. It is grown in more than 170 countries in the world. The world onion production in 2017 was about 97,862,928 tons of dry bulbs from 5,201,591 hectares of land with an average yield of 18.8 t ha⁻¹. China is the biggest onion producer followed by other major onion producing countries India, the USA, Iran, Egypt, Russia and Turkey (FAO, 2017). The estimated total area under onion in Ethiopia was about 31,673.21 hectares, from which 293,887.5 tones were produced in 2018 with an average yield of about 9.27 t ha⁻¹(CSA, 2018). This indicates the productivity of onion in Ethiopia (9.27 t ha⁻¹) is far below the world average 18.8 t ha⁻¹(FAOSTAT, 2012). The factors affecting onion production could be inappropriate use of fertilizer rates, poor fertilizer application and unavailability of quality seeds together with other agronomic practices (FAO, 2017).

Onion is also considerably important in the daily Ethiopian diet for the preparation of traditional foods where the bulbs and the lower section of the stems are used as a seasoning (MoARD, 2005) It has also a long history in medicinal values in that its compounds have been reported to have a range of health benefits. The crop has, among others, anti-carcinogenic properties, anti-platelet and antithrombotic activities and antibiotic effects while it is also effective against the common cold, heart disease, diabetes, osteoporosis, and other diseases (Griffiths *et al.*, 2002).Ethiopia has diversified agro-climatic conditions suitable for the production of a broad range of vegetables including onion. According to Lemma Dessalegn *et al.* (2006), onion production is successful under mild climate without extremes of heat or cold and excessive rainfall in the country.

It is predominantly produced as cash crop for local consumption and regional export market by smallholder farmers throughout the country (MoARD, 2005). It contributes significant nutritional values to the human diet and has medicinal properties and is primarily consumed for its unique flavors or for its ability to enhance the flavors of other foods (Lemma and Shimeles, 2003). In Ethiopia, onion is one of the most important cash crops, which contributes to commercialization of the rural economy and creates many off-farm jobs (Nikus and Fikre, 2010). In Ethiopia, several production constraints cause low productivity of onion, which include lack of appropriate agronomic package, low fertility of the soil, inappropriate use of fertilizer rates, shortage of seeds of improved varieties, diseases, insect pests and poor extension services, high costs and limited availability of commercial fertilizer to small-scale farmers, especially at the peak growing period are the majors (Melkamu A, 2015).

Fertilizers are available mostly for main season crops. For irrigated vegetable crops like onion fertilizers are not available in sufficient quantity (Melkamu *et al.*, 2015). Low soil fertility is one of the most important constraints limiting onion production (Gete *et al.*, 2010). Onion is weak in extracting nutrients, especially the immobile types, because of their shallow and un-branched root system; hence they require and often respond well to the addition of fertilizers (Abd El-Samad, *et al.*, 2012). The availability of high yielding varieties that are adapted to the specific growing area is crucial in increasing the productivity of onion (Tesfalgn, 2015). Therefore, nutrients play a significant role in improving productivity and quality of onion. Since the starting of application in the early 1970's, fertilizer use in Ethiopia had focused mainly on the use of N and P fertilizers in the form of blanket recommendation where, urea and di-ammonium phosphate (DAP) were being applied for almost all crops. Such unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils (Fayera *et al.*, 2014).

Fertilizer usage is one of the instruments implemented as a means of raising production and income of farm and households. However, the extent to which fertilizers are used still

differs considerably between various regions of the world. In Ethiopia, di-ammonium phosphate (DAP) and urea were the commonly used chemical fertilizers for crop production with having a common consideration of nitrogen and phosphorus were the major limiting nutrients for Ethiopian soils. Most Ethiopian soils are deficient in macronutrients (N, P, and S) and micronutrients (Cu, B, and Zn) (ATA, 2016). Yields has not increased as expected even when the recommended rates of N and P fertilizers are applied. This is mainly due to the use of two types of fertilizers (DAP and Urea) alone and this may cause unbalanced fertilizers to use (Hassan, 2010). Plant growth and crop production require an adequate supply and balanced amounts of all nutrients, but the old practice that only uses urea and DAP lacks the use of micronutrients and S.

Since the deficiency of micronutrients is reported in tropical soils, necessitate the application of nutrient sources that reduce such deficiencies. This can only be achieved if the nutrient content of the fertilizer fits to the needs of the crops. Because of its shallow root system, onion requires high level of soil fertility for high yield (Hossain, 2007). Many scholars reported that growth and bulb yield of onion responded positively to the combined application of Nitrogen and Sulfur nutrients at different doses (Nasreen, 2007). According to Assefa *et al.* (2015) finding and using the optimum amount of fertilizer nutrients substantially increases the productivity of onion bulbs beside to using of improved cultivars. Because of Onion is one of the heavy feeders vegetable crop, it requires more mineral fertilizers than other vegetables for a bulb and shot growth (Yohannes *et al.*, 2013). As Khalid (2019) raveled application of micronutrient have a significant improvement on onion yield at a rate (0.5%) of zinc sulfate, iron sulfate (at 1.0%), and boron (at 0.5%).

The use of commercial fertilizers in Ethiopia has not been in harmony with the economy of the farmers mainly since farmers were not using the fertilizer based on soil and crop requirements, while at the same time, the yield return from the applied fertilizers was low. This is because blanket application of DAP and urea was not based on crop need,

soil nutrient dynamics and agro ecological factors (Abreha and Yesuf, 2008), which leads to either nutrient toxicity or deficiency (Ray *et al.*, 2000). However, the Ethiopian Soil Information System (EthioSIS, 2013) indicated that Ethiopian soils lack about seven nutrients (N, P, potassium (K), sulfur (S), copper (Cu), Zinc (Zn) and boron (B) in soil fertility assessment study conducted in different Woredas and Kebeles. According to ATA(2013) the current study area soils were reported to be deficient in S, Zn, B nutrients besides N and P. Different fertilizer materials would be required containing all or most of the nutrients required by crops to ensure balanced fertilizer use (Habte and Boke, 2017). Therefore, applying blended fertilizers containing these deficient essential nutrients to the soil may resolve the problems that limit onion productivity. The Ministry of Agriculture of Ethiopia has been recently introduced a new blended fertilizers like (NPS), (NPSB), (NPSZn) (Tegbaru, 2016)

Onion is produced by traditional farming practices that the farmers lack improved onion production technologies and improved onion seeds are scarce because of undeveloped onion seed production system in the region (Bedru *et al.*, 2009). The seed of onion also imported and distributed informally to growers by traders from abroad without quarantine for its adaptability, germination test and seed viability to different agro ecologies of the country (Kanna, 2016). However, the seed of different improved varieties are obtained from research centers mainly from MARC as a popularization activities being as a national vegetable crops research coordinator, which has been released about eight onion cultivars namely Adama Red, Melkam, Red Creole, Bombay Red, Dereselign, Nafis, Nasika Red and Neptune for different agro-ecologies of Ethiopia based on their different characters and are now in a farming system (Beshir, 2012 and Anna, 2016).The onion cultivars vary in vegetative characteristics such as foliage length, leaf arrangement (erect, pending) and leaf color. They also differ in bulb characteristics, internal structure (single, double, multiple) bulb shape (flat to cylindrical to spindle), color (red, yellow, white), flavor rate (sweet, mid pungent and pungent) (Geremew *et al.*, 2010). Adama Red is a dark red colored and firm, very pungent, flat globe shaped. It flowers and set seed very

easily. It is accepted both by producers and consumers and is successfully produced by small farmers and commercial growers in most regions of the country.

As stated by Kahsay *et al.* (2013), these nationally released varieties employed in the present study were described by EIAR as: Red Creole: red colored and firm, very pungent, not easily bolting, relatively tolerant to purple blotch disease; Bombay Red: thick flat shaped, light red, light pungent, susceptible to purple blotch disease. It has also a high proportion of splitting bulbs and short shelf life compared to the standard onion variety of Adama Red; Dereselgn: early maturing, medium red, large bulb sizes and fits to short growing season; Nasik red has erect leaf arrangement, medium red bulb skin color and 90-110 maturity days. Nafis has erect leaf arrangement, medium red bulb skin color and 90-100 maturity days (EARO, 2004)

Onion is one of the most important vegetable crops cultivated in Enemore Woreda of Gurage Zone both for household consumption and income generation (marketing). It is largely grown under supplementary irrigation condition during the dry season. However, its productivity in the area is (7.8 t/ha) very low compared to the world average (18.8 t/ha) and the national too.

The traditional production practices employed by smallholder farmers also contributes to the low productivity of onion in the area. Such poor practice includes mainly inadequate rate and inappropriate type of fertilizer applications (Fekadu and Dandena, 2006). This is on top of using the blanket recommendation of Urea and DAP at national level. Although some farmers are conventionally using chemical fertilizers for onion, the rate of application is by far below the national blanket recommendation, which is about 105kg N ha⁻¹ and 92kg P₂O₅ ha⁻¹ (Ethiopian Institute of Agricultural Research EIAR, 2007). Since the conventional fertilizer types applied in the Ethiopian agriculture system are Urea and DAP (Di-ammonium Phosphate), which contain only nitrogen and phosphorous, there is a general consensus among researchers and extension workers that this may not be

enough to satisfy the nutrient requirements of the crops across different soil types and locations.

To avoid this situation the Ministry of Agriculture of the country has recently introduced new compound/blended fertilizers, which contain nitrogen, phosphorous, sulfur, boron and Zinc with the ratio of (19% N, 38% P₂O₅ and 7% S (NPS fertilizer), NPSB the ratio of (18.9%N, 37.7%P₂O₅, 6.95%Sand0.1%B) and NPSZn (18%N, 35.9% P₂O₅, 7.7%S, 2.2%Zn) that substituted DAP in Ethiopian agriculture. However, farmers were apply fertilizers without the suitable type for onion crop in the area; In view of this; this experiment was initiated to examine the effect of different types of fertilizer on yield and yield components of onion varieties at Enomore Woreda conditions of the Gurage Zone.

1.2. Objectives of the Study

1.2.1. General objective

- ❖ To examine the effect of different types of fertilizer on yield and yield components of onion varieties in Enemore Woreda of the Gurage Zone

1.2.2. Specific objectives

- To evaluate the effect of application of fertilizers on yield and yield components of onion varieties in Enemore Woreda of Gurage Zone
- To identify the best interaction of varieties and fertilizer on yield and yield components of onion varieties in Enemore Woreda, Gurage Zone
- To evaluate the economic feasibility of the fertilizers on onion production in Enemore Woreda

2. LITERATURE REVIEW

2.1. Botany and Origin of Onion

Onion being a biennial crop, takes two seasons for seed production. It is mainly grown for bulbs; although the green shoots of salad onion is also an important part. Drained friable loam soil with a pH of 6.0 to 6.8 is good for better yield (Brewster, 1994) The Onion bulb consists of the swollen bases (sheaths) of bladed leaves surrounding swollen bladeless leaves. Each leaf consists of a blade and sheath. Collectively, the grouping of these sheaths comprises the pseudo stem. Leaves arise from the short, compressed, dislike stem which continues to increase in diameter with maturation and resembles an inverted cone. The onion skin is formed from the dry paper like outer most leaf scales that lose their freshness during blubbing. Major bulb features are uniformity of shape, size and skin color, pungency and dry matter content (Brewster, 1989).

Onion (*Allium cepa* L.) belongs to the family Alliaceae and the genus *Allium* (Hanelt, 1990). The genus contains about 750 species, among which onion, Japanese bunching onion, leeks and garlic are the most important once (Robinowitch and Currah, 2002). Onion is herbaceous biennial monocot but cultivated as an annual crop for bulb production. For seed production onion is cultivated as biennial crop, in the first season bulbs are formed while flower stalks and seeds are developed in the second season (Lemma Dessalegn, 1998). The onion bulb consists of the thickened bases of leaves attached to a small conical stem. The bulb varies from flat to round in shape. Leaves are long, round and hollow. Flowers are small in size and formed at terminal tip of the stems as umbels (Norman, 1992). The primary center of origin of onion is Central Asia with secondary center in Middle East and Mediterranean Region (Zohary and Hopf, 2000, Grubben and Denton, 2004).

2.2 Distribution and Importance of Onion

Onions are one of the most ancient vegetable crops under cultivation. Onion has been widely distributed to various countries of the world. Currently onions are grown in more than 170 countries in the world. The world onion production in 2017 was about 97,862,928 tons of dry bulbs from 5,201,591 hectares of land with an average yield of 18.8 t ha⁻¹. China is the biggest onion producer followed by other major onion producing countries India, the USA, Iran, Egypt, Russia and Turkey (FAO, 2017). The estimated total area under onion in Ethiopia was about 31,673.21 hectares, from which 293,887.5 tones were produced in 2018 with an average yield of about 9.27 t ha⁻¹(CSA, 2018). This indicates the productivity of onion in Ethiopia (9.27 t ha⁻¹) is far below the world average (18.8 t ha⁻¹).

The factors affecting onion production could be inappropriate use of fertilizer rates, poor fertilizer application and unavailability of quality seeds together with other agronomic practices (FAO, 2017). Onion is probably cultivated in almost all countries of the tropical Africa including Ethiopia (Grubben and Denton, 2004). In Ethiopia, onion is relatively a recent introduction. It was introduced to the agricultural community in the early 1970s through foreigners (Currah, 1990). However, it rapidly becomes a popular vegetable crop widely grown in the country (ETFRUIT, 1992).

According to Lemma and Shimeles, (2003), onion is produced in many parts of the country by smallholder farmers, private commercial growers and state enterprises mainly in Awash Valley, Lake Region and Amhara region around Lake Tana areas where the bulk of dry bulbs and seed are produced (Sisay, 2004, BoFED, 2003). According to recent statistical data from CSA (2014) the production and productivity of onion in Ethiopia is estimated to be about 230,745.2 tons and 10.1t/ha, respectively. In the same production season about 705,877 households were participated in the production of onion. Onion is one the most important cash crops produced by small scale farmers that

helps the farmers to increase their income and thus to improve their livelihood (Lemma and Shimelis, 2003). Its production is likely increasing in the near future because of the expansion of irrigable areas in the country (MoARD, 2005). Onion is by far the most important of all bulb crops cultivated commercially in most parts of the world (Simon, 1992). It is primarily used as flavoring agent in preparing various dishes. Its distinctive pungency is due to the presence of a volatile oil (Malik, 1994). The matured bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B, and C and minerals (Malik, 2000). Moreover, onion has medicinal importance because of its anti-carcinogenic, and antibiotic properties and ant-platelet, anti-thrombotic activities (Griffiths *et al.*, 2002).

2.3. Onion (*Allium cepa* L.) Production Status at the World

The production of onion crop is worldwide because of its wide benefits in our daily foods requirements. Onion is largely produced in the developed nations and has dominated in the international markets due to its higher quality production and longer storage life (Opara, 2003). China is the top producer of the world followed by India and USA (Manna, 2014, Kulkarni *et al.*, 2014). According to FAO STAT (2012), the world total onion production is 742.51 million tons per annum, out of which China shared 205.08 million tons, India 133.72 million tons, and the USA 33.21 million tons respectively.

In Africa, Egypt is the leading country by producing 22.08 million tons of onion per year both for domestic and an international market, which makes it rank as the fourth of producer of the world (Kulkarni *et al.*, 2014). Countries like Turkey, Iran, Afghanistan, Brazil and South Korea also among the major producers and sellers to the international market.

2.4. Ecological Requirement of Onion

Onion can grow between 500m and 2400m. Nevertheless, according to Lemma and Herath (1994), the best growing altitude in Ethiopia is between 700m and 1800m. Onion can be grown in a wide range of climatic environments, but it thrives 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 13 and 24 °C. Optimum temperatures for early seedling growth are between 23 and 27 °C; growth is slowed at temperatures above 30 °C. Acclimatized plants are able to tolerate some freezing temperature. Best production is obtained when cool temperature prevails over an extended period of time, permitting considerable foliage and root development before bulb formation starts.

After bulb formation begins, high temperature and low relative humidity extending into the harvest and curing period are desirable (Purse Glove, 1985; Rubatzky and Yamaguchi, 1997; Jilani *et al.*, 2010). Onion crop can be successfully produced on most fertile soils. The onion crop requires alluvial or sandy loam soil with high levels of organic matter for optimum vegetative growth. The onion crop is a gross feeder since they require high fertile soil to maintain maximum yields (Brewster, 1999). The favorable pH for onion production ranges from 6.2 to 6.8. However, onion crop may also grow on relatively acidic soils (Karim and Ibrahim, 2013). According to Karim and Ibrahim (2013), onion yields however severely reduced in soil salinity.

The onions are grouped into short-days and long-days depending on the day length requirements. The bulbs that acquire day length of 11.5 hours are categorized into short-day group and those that take 14 hours or more for bulb formation fall into long-day group. Onion also requires varying day length and temperature for the purpose they are produced. A relatively high temperature and long photoperiod are required for bulb formation, and for seed production, temperature is of immense importance than day length.

Onion bulbs have specific temperature requirement for seed and bulb production (Baloch, 1994). Light intensity, light quality, and other factors interact with temperature and day length to influence the bulbing response of onion cultivars. With warm weather and bright days, onions bulb at shorter day lengths than when the days are cool and over cast (Hamasaki *et al.*, 1999).

2.5. Importance and Production Status of Onion in Ethiopia

The production of vegetables is becoming important with the expanding irrigated agriculture and with the growing awareness on the importance of the sector as source of income, improved food security, sources of raw materials for industries, employment opportunity because it demands large labor force. The expansion of water harvest schemes in small farmers sector and irrigated agricultural development projects have made significant contribution to the development of the sector. The success of production depends on the adoption of improved technologies such as cultivars that have acceptable standard and high value in the local use and export markets (Lemma *et al.*, 2006).

Ethiopia has a great potential to produce onion throughout the year both for local consumption and for export. It grows best at an altitude of between 700-2200 meters above sea level. Onion is a rapidly becoming popular among producers and consumers. Its popularity among producers is because of the advantage of high yield potential, availability of desirable cultivars for various uses, ease of propagation by seed, high domestic (bulb and seed) and markets in fresh and processed forms (Lemma and Shimeles, 2003). Onion contributes substantially to the national economy, apart from overcoming local demands. With the growing irrigate agriculture in the country, there is a great potential for extensive onion seed and dry bulbs production in the different production belts of the country.

Specifically to onion production and improvement, the Ethiopian Agricultural Research Institute has made efforts to generate different improved varieties. As a result of this effort the varieties Adama Red, Bombay Red, Red Creole, Melkam, Mermiru Brown, Nasik Red and Nafis are made available to farmers (Lemma and Shimelis, 2003; MoARD, 2010). It is widely produced by small farmers and commercial growers throughout the year for local use and export market. Onion is important in the daily Ethiopian diet and all the plant parts are edible, although the bulbs are widely used as a seasoning or a vegetable in various dishes. Onion is valued for its distinct pungency and form essential ingredients for flavoring varieties of dishes, sauces, soup, sandwiches, snacks as onion rings *etc.* It is popular over the local shallot because of its high yield potential per unit area, availability of desirable cultivars for various uses and eases of propagation by seed (Lemma, 2004).

Onion is considered as one of the most important vegetable crops produced on large scale in Ethiopia. It also occupies an economically important place among vegetables in the country. The area under onion is increasing from time to time mainly due to its high profitability per unit area and ease of production, and the increases in small scale irrigation areas. The crop is produced both under rain-fed in the “*Meher*” season and under irrigation in the off season. In many areas of the country, the off season crop (under irrigation) constitutes much of the area under onion production. Despite areas increase, the productivity of onion is much lower than other African countries.

The low productivity could be attributed to the limited availability of quality seeds and associated production technologies used, among the others (Nikus and Mulugeta, 2010). In addition to this, since most of the time onion is produced by smallholder farmers, appropriate agronomic practices employed agricultural inputs such as fertilizers, improved varieties and pesticides are not sufficiently used, and inappropriate postharvest handling practices are done. Generally, farmers produce horticultural crops with traditional farming system that leads to low production and productivity (Melkamu *et al.*, 2015)

Table 1. Specific characteristics/traits of the nationally released varieties of onion in Ethiopia

| Specific characteristics/ traits | Adama Red | Melkam | Red Creole | Bomb y Red | Nasik Red | Nafis |
|----------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Leaf Color | Medium Green | Dark Green | Light Green | Dark Green | Deep Green | Deep green |
| Leaf Arrangement | Erect | Erect | Medium | Medium | Erect | Erect |
| Bulb Size | 60-80cm | 70-90cm | 80-100cm | 85-100cm | 85-100cm | 100-130cm |
| Bulb Shape | Flat Globe | High Globe | Thick Flat | Flat Globe | Globe | Globe |
| Bulb Skin Color | Dark Red | Medium Red | Medium Red | Light Red | Medium Red | Medium Red |
| Bulb Flesh Color | Reddish white | Reddish white | Reddish white | Reddish white | Reddish white | Reddish white |
| Maturity (Days) | 110-130 | 110-130 | 130-145 | <120 | 90-110 | 90-100 |
| Tss (%) | 10-13 | 10-12 | 11-14 | 9-11 | 10-18 | 10-18 |
| Dry Bulb (t/ha) | 35 | 40 | 30 | 30 | 30 | 40 |
| Seed Set | High | High | Medium | High | High | High |

Source: Zeleke and Derso, (2015).

2.6. Response of Onion to Inorganic Fertilizers

2.6.1. Response of onion to nitrogen fertilizers

Nitrogen (N) and phosphorus (P) are referred as the primary macronutrients because of the probability being deficient in plants and their large quantities taken up from the soil

relative to other essential nutrients (Marschner, 1995). The major essential plant nutrients particularly nitrogen (N) and phosphorous (P) are mostly deficient in many soils of tropical Africa (Richardson, 1968) which might also be true for many Ethiopian soils (Murphy, 1959). Nitrogen is an important component of proteins, enzymes, and vitamins in plants. It is a central part of the essential photosynthetic molecule and chlorophyll (Marschner, 1995). Therefore, nitrogen is required by plants in much greater quantities than most of the nutrients and essential to increase onion yield both in quantity and quality (Kafkafi and Genbaum, 1971). The authors also noted that available nitrogen is often a more limiting factor for the plant growth than any other nutrients.

As shallow rooted crop, onion is a heavy feeder of nutrients and require ample amount of nitrogen for optimum yield. Too much nitrogen however can result an excessive vegetative growth and thus delay maturity. Moreover excessive vegetative growth increases susceptibility of onion plants to diseases and reduces dry matter contents and storability of onion bulbs. Consequently excess nitrogen results reduced onion yield both in quantity and quality (Brewster, 1994; Sorensen and Grevsen, 2001).

On the other hand, under sub-optimal supply of nitrogen, onion plants can be severely stunted resulting undersized bulbs and thus reduced yield. Hence, sub-optimal levels of this nutrient in the soil adversely affect the quantity, quality, and storability of onion bulbs. Onion bulb size is related to planting density and smaller bulbs are formed at closer spacing. In such conditions application of increased amount of nitrogen fertilizers is especially important to produce optimum-sized onion bulbs (Rice *et al.*, 1993).

Similarly, Jilani *et al.* (2004) reported that with increase in nitrogen fertilizer up to 120 kg ha⁻¹ N, marketable and total bulb yields were increased, but below this level the total yield t ha⁻¹ began to decrease. According to Kakar *et al.* (2002), increasing nitrogen from 50 to 200 kg ha⁻¹ positively influenced plant height, leaf count, and fresh and dry biomass of onion plants.

Similarly, Negash Aregay *et al.* (2009) reported that increasing the rate of N fertilizer from 0 to 138 kg ha⁻¹ increased total bulb yield from 19.26 t ha⁻¹ to 32.24 t ha⁻¹ and marketable bulb yield from 18.82 t ha⁻¹ to 31.90 t ha⁻¹. Soleymani and Shahrajabian (2012) recorded the highest marketable yield of onion by application of 300 kg ha⁻¹ N while the lowest in control without nitrogen. Generally nitrogen is regarded as nutrient that has the lion share in influencing production and productivity of onion. It is required throughout the growing season. But it is mostly required in larger quantities early in the growing season to ensure optimum leaf and root growth. Peak N uptake is during early bulb growth (Marschner, 1995; Dargie Mirete and Dechassa 2015 and Birhanu Messele, 2016)

2.6.2. Response of onion to phosphorus fertilizers

Phosphorus is claimed to be the second most important plant growth limiting nutrient (Tisdale *et al.*, 1995). It makes about 0.2-0.5% of the plant's dry weight (Bielecki, 1973). Phosphorus is known to be involved in several physiological and biochemical processes of plants; being components of membranes, chloroplasts and mitochondria and constituent of sugar. Phosphorus also played a crucial role in energy transfer reactions and metabolic processes in plant maturity, fruit setting, and seed production (Brady and Weil, 2002; Miller and Donhaue, 1995; Theodorou and Plaxton, 1993). Phosphorus fertilizer had a major effect on yield of onion plant, hence increased total bulb yield and its components. It may be attributed to the enhancement of phosphorus on the plant growth and it's reflected on the bulbs yield.

Many investigators had obtained a similar trend of results (Gupta and Sharma *et al.*, 2000, Shafeek *et al.*, 2004) Phosphorus deficiency is one of the largest constraints to crop production in many tropical soils. The reasons for that is either low content of phosphorus in the soil or high phosphorous fixation (Fairhurst *et al.*, 1999). Therefore, most of the soils throughout the world are phosphorus deficient (Batjes 1997; Zaidi and Mohammad, 2005). Application of phosphorous fertilizers is therefore associated in most

cases with increase in growth and development of crop plants including onion. As reported by Greenwood *et al.* (2001) for example, application of phosphorous fertilizer in soils with moderate phosphorous content enhanced the growth and yield of onion.

Similarly, Singh *et al.* (1998) reported an increase of P_2O_5 from 25 to 100 kg ha⁻¹ decreased weight loss, sprouting and rotting of onions which were stored for 160 days. It is not enough in soils that are relatively low in phosphorous, onion growth and yield can be enhanced by applied phosphorous (Alt *et al.*, 1999).

The presence of phosphorus in the soil encourages plant growth because phosphorus is a major building block of DNA molecules (Pant and Reddy, 2003). In addition, Hinsinger, (2001) reported that the two forms of phosphorus in soil are organic and inorganic. Therefore, inorganic phosphorus is readily absorbed and used by plant if it is not fixed. Phosphorus has been recommended at rates of 33 to 80 kg·ha⁻¹ (Sharma *et al.*, 2003). For instance, results of long term Phosphorus fertilizer trials on loamy sand soils in Germany have shown a strong response of onion to Phosphorus fertilization in the range of 0 to 52 kg ha⁻¹ (Alt *et al.*, 1999). The effects of phosphorus in plant growth are investigated by many workers (Nikolay *et al.*, 1996; Warade *et al.*, 1996; Hinsinger, 2001; Pant and Reddy, 2003 and Shafeek *et al.*, 2004). All of them agreed that, the presence of phosphorus in the soil encourages plant growth, because phosphorus is an essential nutrient.

In the research conducted by Abdulsalam and Hamaiel (2004), increasing the rate of phosphorus fertilizers up to 92 kg ha⁻¹ increased plant height, leaf length and leaf number. In the research conducted in semi-arid region of Ethiopia, onions bulb is increased from application of 200kg ha⁻¹ compared to unfertilized (Shimeles Aklilu, 1997). Aisha *et al.* (2007) also reported that application of phosphorus increased average weight, length and diameter of bulbs and total bulb yield of onion. Similarly, application of 92 kg ha⁻¹ phosphorus fertilizer increased total bulb yield (Shaheen *et al.*, 2007). Generally, application of phosphorus fertilizer positively increased length, diameter, weight dry matter content of onion bulbs, marketable and total bulb yields (Vachhani and Patel,

1993; Boyhan *et al.*, 2001; Aster Kora, 2009). Moreover application of phosphorus fertilizer improved the storability of onion and thus reduced storage losses (Singh *et al.*, 2000).

2.6.3 Response of onion to sulfur fertilizers

Sulfur is also an essential plant nutrient required for growth and development. As macronutrient, sulfur has a positive effect on quality of onion (El-Shafie and El-Gamaily, 2002; Bloem *et al.*, 2004). It is important in the expression of the flavor intensity of bulbs which is associated with pungency (propyl disulfides and other disulfides) and sugars (glucose, fructose, sucrose) contents of onion.

Onion is sulfur loving plant and is required much for proper growth and increased yield of onion (Bloem *et al.*, 2004). The volatile sulfur compounds in onion are released when onion bulbs are cut or bruised through the action of the enzyme allinase. The amount and kinds of sulfur compounds present in the bulb differ with onion varieties. Moreover sulfur is essential for building up sulfur containing amino acids (Anwar *et al.*, 2001). In recent years, sulfur is receiving more attention throughout the world in the production of crops. Application of sulfur to the soil has several effects such as reducing pH, improving soil-water relation and increasing availability of nutrients like P, Fe, Mn and Zn (Marschner, 1998).

Mengel and Kirkby (1982) reported that sulfur is absorbed by plants mainly in form of sulfate, which has minimum competition for absorption with other elements. Sulfur requirements of onion vary with soil texture, leaching losses, sulfur content of irrigation water, previously used fertilizer and amendments containing sulfur (Ahmed, *et al.*, 1988). They reported that the diameter and weight of onion bulbs were significantly improved with the application of sulfur up to 24 kg ha⁻¹. They further reported non-application of sulfur in deficient soils resulted low yield of onion. Since sulfur is essential for chlorophyll formation, its deficiency leads to restricted shoot growth, stiffed stem and

woody and small sized bulbs. However excess sulfur can also increase onion pungency which may be undesirable for fresh market (Bloem *et al.*, 2004).

Onion is a sulfur loving plant and is required much for proper growth and yield of onion (Kumar and Singh, 1995). Sulfur has been found not only to increase the bulb yield of onion but also improves its quality, especially pungency and flavors (Jaggi and Dixit, 1999). Bell (1981) also reported sulfur containing secondary compounds was not only of importance for nutritive value and flavors, but also for resistance against pests and diseases. The yield potential of onion has not been exploited fully as the sulfur fertilizer is used in very low quantity instead of its very high requirement.

Sulfur is essential for building up sulfur containing amino acids in plant cells, particularly in the early stage of plant growth. In recent years, sulfur is receiving more attention throughout the world. Plant sulfur requirements have gained special attention in the last few decades due to the dramatic reduction in atmospheric S-pollutants that caused S deficiency symptoms in many crop species (Haneklaus *et al.*, 2006). Sulfur is essential to protein production in all plant species (Brosnan and Brosnan, 2006).

In crop species producing appreciated secondary metabolites containing S, such as Brassicaceae and Allium, achieving optimal S application is particularly important (McGrath and Zhao, 1996; Lancaster *et al.*, 2001; Al Fraihat, 2009; Garg *et al.*, 2018). Sulfur is available to plants only as sulfate (Haneklaus *et al.*, 2006), hence most S fertilizers consist of sulfate salts, such as gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), sulfate of potassium (SOP, K_2SO_4), ammonium sulfate, or various phosphor-sulfates.

2.6.4. Response of onion to Boron fertilizers

Boron is an essential micronutrient required for normal plant growth and development. It performs wide range of functions in onion plant. It is very sensitive element and plants differ widely in their requirements but the ranges of deficiency and toxicity are narrow. It maintains balance between sugar and starch in plant body (Ali, 2013). It is important in pollination and seed reproduction also. It is necessary for normal cell division, cell wall formation, nitrogen and carbohydrate metabolism and water relation. Information on effect of combined application of S, Zn and B on yield, quality and uptake of nutrients in onion is rather limited. Boron is essential for cell division, nitrogen and carbohydrate metabolism, salt absorption and water relation in plant.

Boron is also required in the translocation of sugars, starches, nitrogen and phosphorus and synthesis of amino acids and proteins (Tisdale *et al.*, 1984). Globally, B deficiency has been recognized as the second most important micronutrient constraint in crops after zinc (Zn) (Farooq *et al.*, 2014). Plants take boron as boric acid, which is easily leached in soils. Minerals are the most common source of boron in soils, with tourmaline (borosilicate) being the most common. Boron is relatively immobile in plant and its availability is essential at all growth stages, particularly during bulb and seed development. Boron has also help to reduce disease severity in some crops because of its effect that B has on plant metabolism, cell membranes and cell wall structure (Dordas, 2009).

Boron reduces the infection of pathogens by improving cell wall and membrane strength with cross-linked polymers and by strengthening the plant's vascular bundles. In addition, boron is essential for important in the synthesis of nucleic acids and cytokinins; facilitates sugar translocation, improves seed germination and seed vigor. Generally blended fertilizer allows small batches of high analysis soil and crop specific fertilizers to be mixed and transported in an economical manner contributing additional profit for

farmers and improving the environment because it provides balanced fertilization (Mekashaw *et al.*, 2020).

2.6.5. Response of onion to Zinc fertilizers

Zinc exerts a great influence on basic plant life process such as nitrogen metabolism, photosynthesis, protein quality and resistance to a biotic and biotic resistance in plants (Potarzycki, and Grzebisz, 2009). Zn involved in auxin (IAA) metabolism like, tryptophane synthesis, tryptamine metabolism, protein synthesis, formation of nucleic acid and helps in utilization of nitrogen as well as phosphorus by plants (Ram and Katiyar, 2013). In plant deficiency of ZnSO₄ affects various plant metabolic processes such as nitrogen uptake, photosynthetic activity, nitrogen metabolism chlorophyll synthesis and protein quality (Cakmak, 2008). According to Alloway (2008), Zinc is essential for the normal healthy growth and reproduction of plants, animals and humans. Micronutrient deficiencies are often induced because of interactions with other nutrients. Zinc uptake was decreased with increasing P application (Oseni, 2009). Plant height, total chlorophyll and biomass were decreased as the amount of Zn concentration in the soil becomes above sufficient level of crops (Mirshekal *et al.*, 2012).

Zinc always has been a significant mineral element for agriculture. Heavy metal zinc is one of the trace elements necessary to the growth of vegetable, but Zn excessiveness also could cause damage. It is essential for regular growth, development and reproduction of plant. Furthermore, application of zinc was found to increase the green pigments of necrotic leaf of plants. The application of Zn significantly increased the bulb weight (73.9 g), bulb yield (45 t/ha) when applied with 2, 4-D (3 ppm) as foliar spray in onion (Trivedi *et al.*, 2013).

3. MATERIALS AND METHODS

3.1. Description of the study area

The experiment was conducted at Terihugn kebele (village Farmers Training Center (FTC), in Enemore Woreda of Gurage Zone, Ethiopia. The site is located at a distance of 192 km from Addis Ababa and 42 km from Wolkite town, the capital of Gurage Zone. The geographical coordinates of the site are 8°7' 30"N latitude and 37° 36' 15" E longitudes. The altitude is 1876 m a.s.l. (Figure 1).The mean annual rainfall is 1150mm and the minimum and maximum air temperatures are 17°C and 21°C, respectively.

The area is characterized by a well-drained silty clay loam soil type three traditional agro-climatic zonation, i.e. Dega” (high altitude), “*Waina Dega*” (mid altitude) and “*Kolla*” (lowlands). The major cereal crops grown in the area, which predominantly grow during the main cropping season under rainfed condition, are maize, wheat and teff. The major horticultural crops that predominantly cultivated under irrigated condition are potato, onion, tomato and cabbage using irrigation (SARI and AGP2, 2016/17).

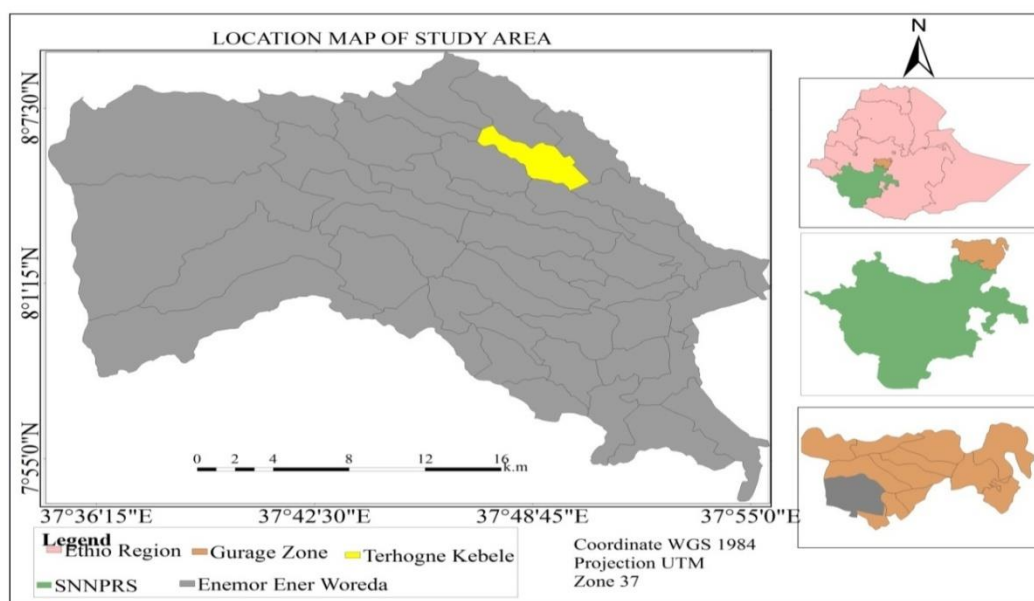


Figure 1. Location map of the study area

3.2. Description of the experimental materials

3.2.1. Planting Materials

Four nationally released onion varieties were used for the experiment. These were: Bombay Red, Red Creole, Nasika red and Nafis. They were obtained from Melkassa Agricultural Research Centre. They were released between 1980, 1984, 2004, and 2010. They are known to be adapted well within an altitude range of 700m-2000m (EARO, 2004).

3.2.2. Fertilizers materials

The four types of fertilizers used for experiment were: (1) DAP (18% N; 46 % P₂O₅); (2) Blended NPS fertilizer (19.0% N, 38.0% P₂O₅, and 7% S); (3) Blended NPSB fertilizer (18.9% N, 37.7% P₂O₅, 6.95% S, 0.1% B) and (4) Blended NPSZn fertilizer (18%N, 35.9%P₂O₅, 7.7% S, 2.2% Zn) and Urea (46%N)

3.3. Treatment and Experimental Design

The experiment was laid out in Randomized Complete Block Design (RCBD) under factorial arrangement with three replications. There were two factors each with four levels. These were: Fertilizers: NP at a rate of 105N and 92 P kg ha⁻¹; NPS at a rate of 105 N,92 P and 17 S kg ha⁻¹; NPSB at a rate of 105 N,92 P,16.96 S and 0.25 B kg ha⁻¹; and NPSZn at a rate of 105N,92P,19.78S and 5.6Zn kg ha⁻¹. The four types of onion varieties include Nasik Red; Red Creole; Nafis; and Bombay Red.

3.4. Treatment Combinations

Table 2. Treatment combinations used for the study area

| | Treatment Combination | Fertilizer type | Variety |
|----|-----------------------|-----------------|------------|
| 1 | F1V1 | NP & Urea | Nafis |
| 2 | F1V2 | NP & Urea | Nasik Red |
| 3 | F1V3 | NP & Urea | Red Creole |
| 4 | F1V4 | NP & Urea | Bombay Red |
| 5 | F2V1 | NPS & Urea | Nafis |
| 6 | F2V2 | NPS & Urea | Nasik Red |
| 7 | F2V3 | NPS & Urea | Red Creole |
| 8 | F2V4 | NPS & Urea | Bombay Red |
| 9 | F3V1 | NPSB Urea | Nafis |
| 10 | F3V2 | NPSB & Urea | Nasik Red |
| 11 | F3V3 | NPSB & Urea | Red Creole |
| 12 | F3V4 | NPSB & Urea | Bombay Red |
| 13 | F4V1 | NPSZn & Urea | Nafis |
| 14 | F4V2 | NPSZn & Urea | Nasik Red |
| 15 | F4V3 | NPSZn & Urea | Red Creole |
| 16 | F4V4 | NPSZn & Urea | Bombay Red |

Table 3. Fertilizer rates used for the experiment

| Treatment Combi | Nutrient rates (kg ha ⁻¹) | | | | | |
|---------------------|---------------------------------------|------------|-------------------------------|------|------|-----|
| Nation | Urea | Adjusted N | P ₂ O ₅ | S | B | Zn |
| 200NP*Nafis | 150 | 105 | 92 | - | - | - |
| 200NP*Nasik Red | 150 | 105 | 92 | - | - | - |
| 200NP*Red Creole | 150 | 105 | 92 | - | - | - |
| 200NP*Bombay Red | 150 | 105 | 92 | - | - | - |
| 242NPS*Nafis | 130 | 105 | 92 | 17 | - | |
| 242NPS*Nasik Red | 130 | 105 | 92 | 17 | - | |
| 242NPS*Red Creole | 130 | 105 | 92 | 17 | - | |
| 242NPS*Bombay Red | 130 | 105 | 92 | 17 | - | |
| 244NPSB*Nafis | 130 | 105 | 92 | 17 | 0.25 | - |
| 244NPSB*Nasik Red | 130 | 105 | 92 | 17 | 0.25 | - |
| 244NPSB*Red Creole | 130 | 105 | 92 | 17 | 0.25 | - |
| 244NPSB*Bombay Red | 130 | 105 | 92 | 17 | 0.25 | - |
| 257NPSZn*Nafis | 130 | 105 | 92 | 19.8 | - | 5.6 |
| 257NPSZn*Nasik Red | 130 | 105 | 92 | 19.8 | - | 5.6 |
| 257NPSZn*Red Creole | 130 | 105 | 92 | 19.8 | - | 5.6 |
| 257NPSZn*Bombay Red | 130 | 105 | 92 | 19.8 | - | 5.6 |

3.5. Experimental procedure

An area of $36.3 \text{ m} \times 11 \text{ m} = 399.3 \text{ m}^2$ was divided into three equal blocks. Each block was being divided into 16 plots, which was allotted at random. The size of each unit plot was $3 \text{ m} \times 1.8 \text{ m} = 5.4 \text{ m}^2$. The onion seedlings were planted in each plot with double row (ridge) system. As recommended by Lemma and Shimeles (2003), the spacing used was 20cm between rows, 10cm between plants and 40cm between double rows. There were 0.5m distance between plots and one meter between replications. Each experimental plot accommodated five double rows with 16 plants in each row and a total of 160 plants.

Seedlings were raised using four seed beds (i.e. one separate bed for each variety). The seedbed was $1 \text{ m} \times 5 \text{ m}$ in size. This was carried out at Terhoge Farmers' Training Center (FTC). A standard nursery soil (3:2:1) was used and the plots prepared appropriately. It was ploughed well with a spade as to be loose and friable as well as obtain good tilth; so that it will provide a favorable condition for the growth of the seedlings. While preparing the land, all weeds, stubbles and dead roots of the previous crop and other vegetation was removed properly.

Onion seedlings were raised on $1.0 \text{ m} \times 5.0 \text{ m}$ seedbed which was well prepared. Seedbed soil was cultivated to a fine tilth before sowing of onion seeds. Good quality seeds of four variety of onion at seeding rate of 4 kg/ha to raise seedlings (EIAR, 2012). The onion seeds were sown in rows at 15 cm apart and lightly covered with soil. Mulching with grasses was done until seedlings emerged (2-5 cm) from the soil. All important cultural practices such as application of water, weed control, diseases and insect pest control activities were undertaken based on the recommendations made for the onion crop (EARO, 2004).

The experimental field was ploughed three times using oxen and plots were leveled manually. Experimental plots of the (16) treatments and three replications (48 plots) were made manually. On each plot - double rows with 40 cm and single rows with 20 cm

between rows were prepared. Healthy and uniform seedlings with 3 to 4 leaf stage or plant height of 12 to 15cm were planted at 10 cm row spacing with 40 cm double rows and 20 cm between single rows were planted on the experimental plots.

Onion seedlings were supplied with full dose of different types of fertilizer (200, 242, 244 and 257 kg ha⁻¹) during transplanting. The remaining dose of urea was applied 35 days after transplanting to facilitate the vegetative growth of onion based on the national recommendation (EARO, 2004).

After 45- 50 days of sowing, seedlings was 3 to 4 true leaf stage with 12-15 cm height, healthy and vigorous seeding were transplanted on well prepared experimental plots were plowed and harrowed using oxen. Replanting of dead seedlings in the field was done one week after transplanting on the place were the first seedlings was planted and all important cultural practices was undertaken based on the recommendations made for the onion crop (EARO, 2004). All necessary subsequent management and agronomic practices such as cultivation, weeding, plant protection and ridging were applied uniformly across all plots of the experiment.

3.6. Data Collection

3.6.1. Soil sampling and Analysis

Soil sample was collected in zigzag pattern before planting from the experimental site at the depth of 20-30 cm from five spots using auger. Then, the samples were collected and composite, air-dried at room temperature under shade and crush with mortar and make to pass through sieve of 2 mm mesh size. the soil sample were analyzed at Wolkite soil laboratory for important soil physical and chemical properties like for particle size distribution (soil texture), soil pH, Cation Exchange Capacity (CEC) , organic matter (%), available phosphorus (mg kg⁻¹) and total Nitrogen (%) available sulfur mg kg⁻¹, available boron (mg kg⁻¹) and available zinc (mg kg⁻¹).

Soil pH was determined by 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter. Soil textural class was determined by Bouyoucos hydrometer method (Bouyoucos, 1962). Organic carbon content of the soil was determined by the volumetric method based on the oxidation of organic carbon with acid potassium di-chromate (K₂Cr₂O₇) medium using the Walkley and Black (1934) method. Total nitrogen was determined by the conversion method. Available phosphorus (ppm) was determined by the Olsen's method (Olsen *et al.*, 1954). Available sulfur (meq/l SO₄⁻²) was determined by mono-calcium phosphate extraction method (Hoefl *et al.*, 1973), and available boron was determined using hot water method (Havlin *et al.*, 1999). Cation Exchangeable Capacity (CEC) was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye, 2000).

3.6.2. Growth parameters

Days to maturity (days):- The number of days elapsed from the time of transplanting up to the date when 80% of plants became dry and collapsed at the neck was counted and the mean values were computed and used for further analysis.

Average Plant height (cm): Plant heights of twelve randomly selected plants were measured from the soil surface to the top of the longest leaf using a ruler at physiological maturity and the mean values were computed for further analysis.

Average Leaf length (cm): The longest leaves of twelve randomly selected plants from central rows at physiological maturity were measured from the point of their emergence using a ruler and expressed as a mean value in centimeter (cm) and used for further analysis.

Average Leaf number: Number of leaves of twelve randomly selected plants per plot was counted at physiological maturity and the mean values were computed.

3.6.3. Yield and Yield Componente parameters of onion

Average bulb fresh weight (g): The average fresh weight of twelve randomly taken mature bulbs measured by using sensitive balance and finally then expressed in gram and the mean values were computed

Average Bulbs dry weight (g): The mean bulb weight of twelve randomly selected plants at harvest was computed and use for further analysis (GueshTekle, 2015).

Average Bulb diameter (cm): The mean size of the bulb at harvest was computed by measuring the diameters at the middle of twelve randomly selected bulbs in each plot using caliper (Lemma and Shimeles, 2003).

Marketable bulb yield ($t\ ha^{-1}$): Bulbs which were free of mechanical, disease and insect pest damages, uniform in color and medium to large in size were consider as marketable. The weight of such bulbs obtained from the net plot area of each plot was measured in kilogram using scaled balance and expressed as ton per hectare (Lemma and Shimeles, 2003).

Unmarketable bulb yield ($t\ ha^{-1}$): Harvested bulbs which were misshaped, decayed, discolored, diseased and physiologically disordered were considered as unmarketable according to Lemma and Shimeles (2003). The weight of such bulbs obtained from the net plot area of each plot was measured in kilogram using scaled balance and expressed as ton per hectare.

Total bulb yield ($t\ ha^{-1}$): Total yield of onion was obtain by adding marketable and unmarketable bulb yields and expressed as ton per ha (GueshTekle, 2015).

3.6.4. Economic Analysis (Partial Budget Analysis)

Economic analysis was performed to investigate the economic feasibility of the treatments by using partial and marginal analyses. The gross income was obtained by multiplying average marketable bulb yield by the average open market price (Birr kg⁻¹). Total variable cost was the cost of fertilizers, cost of fertilizer application and seed cost. Labor costs to apply fertilizer were calculated considering per person per day: Net benefit = Gross income - total variable cost (International Maize and Wheat Improvement Centre (CIMMYT) 1988). Dominance analysis was conducted by listing the treatments according to increasing order of costs that vary and comparing the net benefit of the treatments. Treatments found with decreasing net benefit while, total cost that vary increases were eliminated (Dominated). Marginal rate of return were computed for those which was none dominated. Marginal rate of return (MRR) were calculated as the change in net benefit (NB) divided by the change in total variable cost (TVC) of the successive net benefit and total variable cost levels (CIMMYT 1988). Marginal increase in net benefit Marginal rate of return (MRR) = Marginal increase in cost. So to assess the current costs and economical optimum rates of DAP and Urea, NPS, NPSB, and NPSZn fertilizer.

3.7. Statistical Analysis

All the collected data were first checked for fitting the analysis of variance (ANOVA) and examined for normality assumptions. Collected data were subjected to analysis of variance (ANOVA) using SAS, version 9.3 software, General Linear Model (GLM) procedures (SAS Institute, 2014). Means were separated using the Least Significant Difference (LSD) at 5% depending on ANOVA results. Correlation analysis between each parameter was carried out using simple linear correlation coefficients (SAS).

4. RESULTS AND DISCUSSION

4.1. Soil Physicochemical Properties of the Experimental Site

4.1.1. Soil Physical Properties

Analysis of soil samples for selected soil physicochemical properties before planting was presented in (Table 4). Soil analysis results indicated that the soil textural class was silty clay loam with a particle size distribution of 34% clay, 46% silt and 20% sand.

4.1.2. Soil Chemical Properties

The soil pH of the experimental field showed that the field has a pH of 6.8, which is under slightly acidic category. Hence, soil pH is a very important soil property due to its ability to determine the availability of nutrients for plant uptake (El-Attar *et al.*, 1973). The soil pH level that allows for a wider nutrient availability to crops is in the 5.5 to 7.5 range (Chopra and Kanwar, 1976).

The CEC of the experimental site was 63.25 cmol (+) kg⁻¹ soils, which are under medium category (Lendon *et al.*, 1991) (Table 4). The soil organic carbon content of the study area was 1.404 which is under Low range as described by Walkley and Black, (1934). Total nitrogen value was 0.121% (Table 4). According to Kjeldahl method, (1973) classified soil nitrogen as N content < 0.1% was rated as very low, 0.1-0.2% as low, 0.2-0.5% as medium (sufficient), 0.5-1.0% as > 1% is very high. Therefore, the experimental site can be classified in low range in its total N content.

Available P content of the experimental site was 4.68 ppm of the soil sample solution. According to Hazelton and Murphy (2016), the range of phosphorus in Bray method is < 7, 8-19, 20-39, 40-58 and >59 is regarded very low, low, medium, high and very high respectively. Hence, in this regard, the phosphorus content of the study area is very low and it needs phosphorous fertilizer. Available sulfur value of the study area was 17.83 mg kg⁻¹ (Table 4). According to Horneck *et al.*, (2011) sulfur values categorized under

medium range. Hence application of maintenance rate of sulfur fertilizer is needed for the study area.

The available boron value of the study area was 0.08 mg kg^{-1} (Table 4). According to Benton (2003), the critical level of boron value for most Ethiopian soils is $1.1 - 2 \text{ mg kg}^{-1}$. Below this range, it is regarded as boron deficiency. Hence, the soil of the study area is deficient in its boron content, which implies the application of boron containing fertilizers is essential to offset the balance. As reported by Moraghan and Mascagni (1991), boron concentration and its bioavailability in soils is affected by several factors including parent material, texture, nature of clay minerals, pH, liming, organic matter content, sources of irrigation, interrelationship with other elements, and environmental conditions like moderate to heavy rainfall, and high light intensity.

The available zinc value of the study area was also found to be 1.3 ppm (Table 4). Benton (2003) classify the soil's zinc content as < 0.2 very low, $0.3-1$ low, $1.1-2$ optimum, $2.1-4$ high and $> 4.1 \text{ ppm}$ is very high. In this regard, the zinc content of the study is optimum or sufficient to support the growth and development area. In other words, despite some of the results that show better plant height and leaf number, there is no need to use or apply zinc containing fertilizers. On the other hand, those results of better performance on plant height and leaf number could be attributed the combined effects of the other elements within the blended fertilized.

Table 4. Analysis results of the soil physicochemical properties of the experimental/study site

| Soil Physical Properties | Value |
|-----------------------------|-----------------|
| Sand (%) | 20 |
| Silt (%) | 46 |
| Clay (%) | 34 |
| Textural class | Silty clay loam |
| Soil Chemical Properties | |
| pH (1:2.5 H ₂ O) | 6.8 |
| TN (%) | 0.121 |
| OC (%) | 1.404 |
| CEC cmol kg | 63.25 |
| Av. Phosphorus (ppm) | 4.68 |
| Av. Sulfur (ppm) | 17.83 |
| Av. Zinc (ppm) | 1.3 |
| Av. Boron (ppm) | 0.08 |

CEC=Cation exchange capacity, OC=Organic carbon, OM= Organic Matter, TN=Total nitrogen, Av. = Available= P = phosphorus, Av. = Available, S = sulfur, Av. = Available Zn = zinc=boron, ppm = parts per million.

4.2. Phonological and growth Parameters of Onion

4.2.1. Days to 80% of physiological maturity

The analysis of variance indicated that the main effects of number of days to physiological maturity of onion was significantly ($P < 0.01$) affected by different types of fertilizer, and type of varieties. However the interaction between these two factors was not significant (Appendix Table 1). The application of NPSZn fertilizer recorded the longest day to physiological maturity of onion (119.83days) that compared to fertilizer type with NP. The longest days to physiological maturity (117.66 and 116.83 days) were recorded variety Bombay Red and Red Creole compared with variety Nafis (105.66 days) variety Nafis which was by about 12 days earlier (Table 5). Similarly Azoom *et al.*

(2014) also reported significant differences among eight onion varieties for days to bulb maturity. Bombay Red and Nafis matured by less than 120 or and in between 110 to 130 days, respectively.

Similarly, Aynewa *et al.* (2013) reported significant difference among genotypes on days to maturity. Besides, the number of days required to attain 80% physiological maturity of onion varieties proportionally it increased with blended NPSZn fertilizer type. This could be due to the presence of N, P, S and Zn plant nutrients which played an important role in protein synthesis, formulation of some growth hormone that prolong crop on field duration and promote bulb maturation and production. Similarly, Abebaw and Hirpo, (2018) described application of a blend fertilizer (macro and micro) and urea, which has a higher rate of nitrogen nutrient, prolongs the vegetative growth of onion. Phosphorus also enhances photosynthesis and nitrogen uptake, which contribute to availability of more nitrogen for vegetative growth of onion (Shaheen *et al.*, 2007).

Sulfur is also a vital nutrient for life and essential for plant growth due to synthesis of proteins, vitamins containing amino acids and associated with nitrogen metabolism for chlorophyll formation (Zhao *et al.* 1999). This could be associated with the combined effect of nutrients including nitrogen found in the compound NPSZn fertilizer in extending the vegetative growth period of plants while delaying maturity.

The results are in agreement with the findings of various researchers (Demoz Kidanie, 2016; Mekides Mekashaw, 2016; Minwyelet Jemberie, 2017; Shege Getu *et al.*, 2017; Melkamu Alemayehu and Minwyelet Jemberie, 2018) who observed extended vegetative growth of various vegetables including onion with higher rates of NPS, NPSB and NPSZn fertilizers as well as of nitrogen. Similarly, Sorensen and Grevsen (2001) observed that too much nitrogen promoted excessive vegetative growth and delayed maturity that synthesis of proteins and formation of new tissues are stimulated, resulting in vigorous vegetative growth. This increases the days of physiological maturity.

Table 5. Main effect of different varieties and fertilizer types on days to maturity of Onion

| Treatment | Days to maturity |
|---------------------------------------------|-------------------------|
| Varieties | |
| Nafis | 105.66 ^c |
| Nasik Red | 107.83 ^b |
| Red Creole | 116.83 ^a |
| Bombay Red | 117.66 ^a |
| LSD (0.05%) | 2.00** |
| CV (%) | 2.14 |
| SE ± | 0.8 |
| Fertilizer type (kg ha⁻¹) | |
| NP | 104.41 ^d |
| NPS | 108.25 ^c |
| NPSB | 115.5 ^b |
| NPSZn | 119.83 ^a |
| LSD (0.05) | 2.00** |
| CV (%) | 2.14 |
| SE ± | 0.8 |

Means followed by the same letter in the same column and in the same factor not significantly different at 5% probability level. LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.2.2. Average plant height (cm)

Result from the analysis of variance revealed that the main effects of different types of fertilizers and variety significantly ($P < 0.01$) influenced plant height of onion. However, their interaction effect did not significantly influence plant height (Appendix Table 2).

The highest plant height (60.8cm) was recorded by blended NPSB fertilizer type that compared to (47.94cm) in the use of NP fertilizer type (Table 6).

As Bungard *et al.*, (1999) stated, the probable reason for higher plant height could be due to the increased of nitrogen application that played a significant role in the building block of amino acids, enhancing cell division, cell elongation, chlorophyll synthesis, and protein synthesis.

The higher (59.5 cm) mean plant height was recorded by the Red Creole compared to Nafis variety (52.17 cm) (Table 6) this could be attributed to the difference in their genetic makeup. Similar findings by Tegbew *et al.* (2011) and Tesfalgn *et al.* (2015) stated maximum plant height for Red Creole variety as compared to Nafise variety. The result was in agreement with the finding of Arif *et al.*, (2006) and Teklu *et al.*, (2019) that showed a combination of macro and micro nutrients (nitrogen and phosphorous with sulfur and born) can increase plant height with increasing doses as well as a combination based on varietal responses.

This result is in agreement with Nasreen *et al.* (2007), Gustfson *et al.* (2010) and Agumas *et al.* (2014) who reported that the application of nitrogen fertilizer increases the vegetative growth of onion due to its potential to increase photosynthesis rate. Moreover, phosphorus enhances photosynthesis and encouraged root growth because it has a vital role in energy transfer held as a part of the chemical structures of ADP and ATP that drives the chemical reactions within the plant.

Sulfur is important in the building up of protein and a key ingredient in the formation of chlorophyll (Ghaffoor *et al.*, 2013). This is in agreement with the finding of Bloem *et al.* (2004) who stated that onion is a sulfur loving plant, which is required for proper growth and bulb development. Boron is also an essential micronutrient that is necessary for normal cell division, nitrogen metabolism, protein formation, and phosphorus uptake (Ghaffoor *et al.*, 2013).

Mirete and Dechassa (2015) reported that increasing the rate of nitrogen fertilizer to 96 kg N ha⁻¹ significantly increased plant height. Ali *et al.* (2018) also reported that different

phosphorus levels significantly affect plant height, wherein the tallest plants were observed at higher rates.

Table 6. Main effect of different varieties and fertilizer type on plant height of Onion

| Treatment | Plant height(cm) |
|--------------------------------------------|-------------------------|
| Varieties | |
| Nafis | 52.17 ^b |
| Nasik Red | 53.1 ^b |
| Red Creole | 59.5 ^a |
| Bombay Red | 54.9 ^b |
| LSD (0.05) | 3.55** |
| CV (%) | 7.78 |
| SE ± | 1.42 |
| Fertilizer type(kg ha⁻¹) | |
| NP | 47.94 ^b |
| NPS | 50.34 ^b |
| NPSB | 60.8 ^a |
| NPSZn | 60.6 ^a |
| LSD (0.05) | 3.55** |
| CV (%) | 7.78 |
| SE ± | 1.42 |

Means followed by the same letter in the same column and in the same factor not significantly different at 5% probability level; LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.2.3. Average leaf length (cm)

The analysis of variance for the interaction effects of different types of fertilizer and varieties showed significant ($p < 0.05$) difference in leaf length of onion (Appendix Table 3). The maximum leaf length of onion (60.87 cm & 59.9 cm) was recorded NPSZn and NPSB blended fertilizer type with variety Red Creole while the minimum leaf length NP fertilizer type with Nafis Variety (36.52 cm) (Table 7).

This result is in agreement with the finding of Birhanu *et al.* (2016) who reported a positive effect of nitrogen on leaf length may be due to its role in chlorophyll, enzymes, and protein synthesis. Similarly, Jilani *et al.* (2004) reported an increase in the length of onion leaves with an increase in nitrogen rate.

This is consistent with Gustafson *et al.* (2010) who reported that the increase in leaf length is attributed to phosphorus to form good root systems and strong stem, particularly in crops with restricted root systems like onion, thereby enhance the ability of the plant to explore nutrients vital for leaf growth. Fatma *et al.* (2014) obtained the application of sulfur holding fertilizer positively affected all onion growth variables. Boron also maintains a balance between sugar and starches in the plant body that sugar and carbohydrates in different parts of the plant body which increases vegetative growth of onion.

Sankaran *et al.* (2008) also reported that the application of sulfur at 45 kg ha^{-1} significantly increased the uptake of N, P, and K. Hänsch and Mendel (2009) stated essential role of boron in improving plant growth, through biosynthesis of endogenous hormones. Ghaffoor *et al.* (2013) also reported that the application of phosphorus at 100 kg ha^{-1} produced higher onion leaf length.

The increase in leaf length and diameter of onion leaves can be associated again with the fact that nitrogen is important for plant cell division and elongation (Brady, 1990; Marschner, 1995). Moreover, nitrogen plays significant role for the synthesis of chlorophyll, enzymes and proteins which are important for plant growth including onion.

As noted before, nitrogen is the major constituent of proteins and its abundant presence tends to increase the size of the leaves, which brings about an increase in carbohydrate synthesis (Bungard *et al.*, 1999).

The results of this study is in agreement with Muhammad (2004) and Jilani (2004) who reported that the length and width of onion leaves increased with increased nitrogen rates. The difference of varieties in leaf length also might be their differences in genetic makeup. Similarly, Mondal *et al.* (1986) Ghafoor *et al.* (2003) and Jilani *et al.* (2010) also reported the differences among cultivars with respect to leaf length.

Table 7. Interaction effect of different fertilizer type and varieties on Leaf Length of Onion

| Varieties | Fertilizer kg ha ⁻¹ | | | |
|------------|--------------------------------|----------------------|---------------------|----------------------|
| | NP | NPS | NPSB | NPSZn |
| Nafis | 36.52 ^e | 40.63 ^{cde} | 51.91 ^{ab} | 47.46 ^{bcd} |
| Nasik Red | 36.99 ^e | 39.11 ^{de} | 39.03 ^{de} | 40.02 ^{cde} |
| Red Creole | 41.3 ^{cde} | 38.97 ^{de} | 59.9 ^a | 60.87 ^a |
| Bombay Red | 39.88 ^{cde} | 40.88 ^{cde} | 48.75 ^{bc} | 49.1 ^{bc} |
| LSD (0.05) | 2.41*** | | | |
| CV (%) | 6.51 | | | |
| SE ± | 0.96 | | | |

Means followed by the same letter(s) are not significantly different at (P < 0.05); LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.2.4. Average leaf number

The analysis of variance for the interaction effects of different types of fertilizer and variety showed significant (p < 0.01) difference in leaf number of onion (Appendix Table 4). Plants with the highest mean leaf number were produced in response to application of the fertilizer NPSB & NPSZn combined with variety Red Creole (14 and 13.66) respectively. However, the lowest (7.00) number of leaves per plant was recorded in the NPS treatment for Nasik Red variety (Table 8).

The possible reasons for observed highest number of leave per plant could be due to the availability of enough plant nutrients through the application of NPSB & NPSZn fertilizer that positively influenced the vegetative growth of the plants. These nutrients contained the synthesis of the different components of protein required for leaf development, photosynthesis and metabolic processes required for plant growth. The reduced leaf number at a lower level of fertilizer might be due to the lack of sufficient nutrients and assimilate for growth. The increase in leaf number per plant at type of NPSB & NPSZn blended fertilizer could be attributed to the availability of macro and micronutrients that permit leaves to grow vigorously. Nitrogen and sulfur fertilization had the potential to increase nutrients availability in the soil and thus enhance the uptake of nutrients by the plant. The result of the present work is in line with the finding of Nasreen *et al.* (2007) who reported that the application of 120 kg N ha⁻¹ significantly increased the number of leaves per plant of onion, and a further increase of nitrogen supply to 160 kg ha⁻¹ tended to decrease it. Abdissa and Pant (2011) reported that nitrogen fertilization significantly influenced the number of leaves produced by the onion plant.

Uzma *et al.* (2016) reported that a low level of phosphorus fertilizer application results in a reduction in leaf expansion and leaf surface area, as well as the number of leaves in garlic. Similarly, Nasreen *et al.* (2011) reported maximum plant height and leaf number when sulfur was applied at the dose of 45 kg S ha⁻¹. Manna *et al.* (2014) also obtained the maximum number of leaves as a result of a 0.1% boron application.

Table 8. Interaction effects of different types of fertilizers and Varieties on Leaf number

| Varieties | Fertilizer Type kg ha ⁻¹ | | | |
|------------|-------------------------------------|-------------------|--------------------|-------------------|
| | NP | NPS | NPSB | NPSZn |
| Nafis | 7.16 ^b | 8.33 ^b | 9.00 ^b | 8.00 ^b |
| Nasik Red | 7.66 ^b | 7.00 ^b | 7.66 ^b | 8.33 ^b |
| Red Creole | 9.33 ^b | 8.33 ^b | 13.66 ^a | 14.0 ^a |
| Bombay Red | 8.83 ^b | 8.00 ^b | 9.00 ^b | 8.66 ^b |
| LSD (0.05) | 1.05** | | | |
| CV (%) | 14.09 | | | |
| SE ± | 0.42 | | | |

Means followed by the same letter(s) are not significantly different at (P < 0.05); LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.3. Yield and Yield Components of onion

4.3.1. Average bulb diameter(cm)

The result of analysis of variance revealed that the main effects of different types of fertilizer and variety and their interaction significantly (P<0.01) influenced the bulb diameter of onion (Appendix Table 5). The application of blended NPSB and NPSZn fertilizer significantly increased the bulb diameter from the lowest value of 4.6 cm for the use of NP fertilizer and Nasik Red to the highest value of 6.13 and 6.1 cm NPSB and combined with Red Creole. The higher photo assimilate accumulation in the bulbs would ensure higher individual bulb weight and large bulb diameter which collectively increases the bulb yield of onion (Dentan, 2004). The probable reasons for wider bulb diameter of onion recorded from plants supplied with relatively high NPSB & NPSZn and variety Red Creole could be due to the presence of enough nutrients (N, P S, B and Zn) that promote the growth and development of plants and consequently the diameters of bulbs. The increase in bulb diameter is obviously associated with increased in dry matter production and allocation of assimilates to the bulb through increased number of leaves, plant height and leaf length and thus higher photo assimilate concentration in the bulbs

that ensure large bulb diameter.(Table 9). Verma *et al.*, Bhonde *et al.*, (1999), reported that the application of Zn and B had a significant positive effect on onion plant height, bulb diameter, and bulb length.

Table 9. Interaction effects of different types of fertilizer and Varieties on Bulb diameter

| Varieties | Fertilizer Type kg ha ⁻¹ | | | |
|------------|-------------------------------------|--------------------|--------------------|--------------------|
| | NP | NPS | NPSB | NPSZn |
| Nafis | 5.2 ^{abc} | 5.4 ^{abc} | 4.9 ^{bc} | 5.3 ^{abc} |
| Nasik Red | 4.6 ^c | 4.8 ^c | 5.1 ^{bc} | 5.4 ^{abc} |
| Red Creole | 5.5 ^{abc} | 5.8 ^{ab} | 6.1 ^a | 6.1 ^a |
| Bombay Red | 5.0 ^{bc} | 5.8 ^{ab} | 5.4 ^{abc} | 5.3 ^{abc} |
| LSD (0.05) | 0.25** | | | |
| CV (%) | 5.67 | | | |
| SE ± | 0.1 | | | |

Means followed by the same letter(s) are not significantly different at (P < 0.05); LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.3.2. Average fresh bulb weight(g)

The analysis of variance showed that different types of fertilizer and variety as well as their interaction effects highly significantly ($P \leq 0.01$) influenced the average bulb weight of onion (Appendix Table 6). The highest mean bulb weight (103.66 and 95 g) was recorded when NPSB and NPSZn fertilizer applied on the Red Creole variety (Table, 10). On the other hand, the lowest average bulb weight (56.26 g) was recorded from crop grown with NP fertilizer and Variety Nafis (Table 10). The use of NPSB fertilizer type and use of Variety Red Creole recorded the bigger bulbs with highest average weight, which could be associated with supply of enough plant nutrients required for growth and development of onion plants and thus bulbs. Such conditions improve the metabolic activities in the plant that lead to increased accumulation and translocation of assimilates from leaves to bulb.

The results of the present study are generally in line with the findings of other researchers (Kumar and Singh, 1992; Baiyeri, 2002; Aliyu`s *et al.*, 2008; Aster Kora, 2009; Mahala,

2015) where application of blended fertilizers like NPS, NPSB or single nutrients like phosphorous and sulfur improved bulb weights of onion. Application of different levels of sulfur, zinc and boron had significant effect on fresh weight of the bulb. This may be due to sulfur, zinc and boron play an essential role in plant growth through the biosynthesis of endogenous hormones which is responsible for promotion of plant growth, and role in cell division, meristematic activity of plant tissue and expansions of cells this in turn results in highest fresh weight of the bulb. The results are similar to Bhatt *et al.*, (2004), Hansch and Mendel, 2009, Katare *et al.* (1971) and Patil *et al.* (2008).

Table 10. Interaction effects of different types of fertilizer and Varieties on Average fresh bulb weight

| Varieties | Fertilizer Type kg ha ⁻¹ | | | |
|------------|-------------------------------------|-----------------------|---------------------|----------------------|
| | NP | NPS | NPSB | NPSZn |
| Nafis | 56.26 ^g | 61.06 ^{defg} | 68.0 ^{de} | 66.0 ^{def} |
| Nasik Red | 64.0 ^{defg} | 59.33 ^{efg} | 58.66 ^{fg} | 59.33 ^{efg} |
| Red Creole | 69.33 ^{cd} | 78.33 ^{bc} | 103.66 ^a | 95.0a |
| Bombay Red | 67.0 ^{def} | 68.33 ^{de} | 85.0 ^b | 78.66 ^b |
| LSD (0.05) | 2.37*** | | | |
| CV (%) | 4.00 | | | |
| SE ± | 0.95 | | | |

Means followed by the same letter(s) are not significantly different at ($P < 0.05$); LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.3.3. Average bulb dry weight(g)

The bulb dry weight of onion was significantly ($P \leq 0.001$) influenced by the main effects of different types of fertilizer and Variety. But the interaction of the two factors was not significant (Appendix Table 7). The maximum bulb dry weight (11.5g) was recorded with the application of NPSB fertilizer that compared with fertilizer type NP with (8.28g). The maximum (11.97 g) mean bulb dry weight was recorded by the Red Creole compared to Nasik Red and Nafis variety (7.65 and 8.73 g) (Table 6) this could be attributed to the difference in their genetic makeup. Similar findings by Tegbew *et al.*

(2011) and Tesfalgan *et al.* (2015) stated maximum bulb dry weight for Red Creole variety as compared to Nafise variety. The result was in agreement with the finding of Arif *et al.*, (2006) and Teklu *et al.*, (2019) that showed a combination of macro and micro nutrients (nitrogen and phosphorous with sulfur and born) can increase plant height with increasing doses as well as a combination based on varietal responses.

The increased bulb dry weight of NPSB fertilizer and variety Red Creole is probably due to the availability of sufficient nutrients with and genetically which finally resulted in better accumulation of photosynthetic in their sink (bulbs) as compared to the NP. Meena and Singh (1998) in their investigation reported that zinc significantly increased dry weight of bulb. The favorable effect of micronutrients on plant growth might be due to their role in many physiological processes and cellular functions within the plants. In addition, they play an essential role in improving plant growth, through biosynthesis of endogenous hormones which are responsible for promoting of plant growth (Battal, 2004).

The yield improvement was due to better growth and development. Higher photosynthesis accumulation in the bulbs would ensure higher individual bulb weight, large bulb diameter and neck thickness. More energy is stored in the bulb because phosphorus is a significant component of nucleic acid that helps the whole plant growth and development.

The results of the present study are in agreement with findings of other researchers who report that an increased in mean fresh bulb weight in response to nitrogen application could be attributed to increase in number of leaves, leaf length and extended physiological maturity that led to increased assimilate production and allocation to the bulbs (KokebeWolde *et al.*, 2013). Yadav *et al.* (2003) and El-Tantawy and El-Beik (2009) also found that higher N doses resulted in the production of higher bulb dry matter yields than lower doses of nitrogen. Fertilizer application that contains sulfur had high utilization of macro and micronutrients and those significantly increase total solids in onion bulbs at maturity (Nasreen *et al.*, 2007), AbdissaYohannes *et al.* (2011) obtained significant increments in bulb weight due to increased nitrogen application. Abraha

Gebrekiros *et al.* (2015) also indicated positive effect of application of N, P, S and Zn fertilizers on growth of onion bulb that has a contribution for bulb weight.

Table 11. Main Effects of different fertilizer type and varieties on bulb dry weight of Onion

| Varieties | Bulb dry weight (g/plant ⁻¹) |
|--------------------------------------------|------------------------------------------|
| Nafis | 8.73 ^c |
| Nasik Red | 7.65 ^c |
| Red Creole | 11.97 ^a |
| Bombay Red | 10.08 ^b |
| LSD(0.05) | 1.3** |
| CV (%) | 16.3 |
| SE ± | 0.52 |
| Fertilizer type(kg ha⁻¹) | |
| NP | 8.28 ^c |
| NPS | 8.85 ^{cb} |
| NPSB | 11.5 ^a |
| NPSZn | 9.8 ^b |
| LSD(0.05) | 1.3** |
| CV (%) | 16.3 |
| SE ± | 0.52 |

The same letter within a column in the same factor are not significantly different at $p < 0.05$

BDW=Bulb dry weight, LSD =List significant difference, CV=coefficient of variance.

4.3.4. Marketable bulb yield(t ha⁻¹)

The analysis of variance revealed that marketable bulb yield of onion was highly significantly ($P < 0.01$) affected by different types of fertilizer and varieties as well as their interaction effects (Appendix Table 8).

The highest marketable yield (31.64 t ha⁻¹) of onion was achieved from treatment combination of NPSB fertilizer and Variety Red Creole, which was statistically similar with marketable bulb yields (27.01t ha⁻¹) of onion plants that received NPSZn fertilizer and Variety Red Creole. The lowest marketable yield (21.06 t ha⁻¹) was recorded from plants grown with 200kg ha⁻¹ NP fertilizer and which was statistically similar with

marketable bulb yields (21.5t ha⁻¹) of onion plants that received (NPS fertilizer with the same Variety Nasik Red (Table 12).

The use of NPSB fertilizer and different varieties increased the marketable bulb yield in the present study. This could be due to the presence of plant nutrients that are required from improved growth and development of onion plants that in turn increased the marketable bulb yield. These conditions also improved the diameter and weight of onion bulbs as indicated above that contributed to higher marketable yield with proper size, shaped and color of the bulbs.

The result agrees with many researchers who reported that application of Nitrogen, Phosphorous, Sulfur, and Boron in their single and blended form have a significant effect on the growth and yield parameters of onion (Nigatu, 2018). Manna *et al.*, (2013) reported that foliar application of boron with zinc significantly increases the marketable and total yield of onion. The yield differences can also be attributed to difference in genetic makeup of different varieties (Mahanthesh, 2008)

Table 12. Interaction effects of different types of fertilizer and Varieties on Marketable bulb yield of Onion

| Varieties | Fertilizer Type kg ha ⁻¹ | | | |
|------------|-------------------------------------|---------------------|---------------------|---------------------|
| | NP | NPS | NPSB | NPSZn |
| Nafis | 21.64 ^{bc} | 22.41 ^{bc} | 22.99 ^{bc} | 24.68 ^{bc} |
| Nasik Red | 21.06 ^c | 21.5 ^c | 23.05 ^{bc} | 23.03 ^{bc} |
| Red Creole | 23.61 ^{bc} | 22.55 ^{bc} | 31.64 ^a | 27.01 ^{ab} |
| Bombay Red | 23.26 ^{bc} | 24.98 ^{bc} | 25.58 ^{bc} | 25.36 ^{bc} |
| LSD (0.05) | 1.38** | | | |
| CV (%) | 6.89 | | | |
| SE ± | 0.55 | | | |

Means followed by the same letter(s) are not significantly different at (P < 0.05); LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

The results of the present study are in agreement with the findings of Muluneh (2016) who observed highest marketable yield of onion with the application of NPSB fertilizer at

the rate of 105:92:16.95: 2.5 kg ha⁻¹ N: P₂O₅: S: B. Application of increasing phosphorus levels also increased significantly length, diameter, weight, and dry matter content of onion bulbs, which contributed to the increased marketable bulb yield of onion (Aster, 2009). El-Shafie and El-Gamaily (2002) and Juszczuk and Ostaszewska (2011) reported that sulfur and nitrogen stimulate the enzymatic actions and chlorophyll formations, which promote the growth and development of the plant leading to high yielding performance.

4.3.5. Unmarketable bulb yield(t ha⁻¹)

Results from analysis of variance revealed that the main effects of varieties highly significantly ($P < 0.01$) influenced the unmarketable bulb yield of onion. But blended fertilizer and interaction were not significant (Appendix Table 9). The highest value of unmarketable bulb yield (1.55 t ha⁻¹) was recorded in variety Nasik Red compared to Red Creole variety (0.66t ha⁻¹) this could be attributed to the difference in their genetic makeup. The lowest unmarketable bulb yield (0.8 t ha⁻¹) was obtained from the application of NPSB fertilizer that compared with fertilizer type of NP (1.01t ha⁻¹) (Table 13). These might be due to the synergetic effect of the applied nutrient nitrogen phosphorus, sulfur, and boron.

Khan *et al.* (2002) indicated that application of fertilizer not only improve average bulb weight but also enhance marketable bulbs and significantly reduce the production of unmarketable bulbs by preventing culling or wastage of too much bulbs. Availability of excess soil nutrients for sub-optimal growth led to over size or weight of bulbs, split bulbs, physiologically disordered, doubles, rotten, off-color and discolor and consequently higher unmarketable yield (Moray *et al.*, 2012).

Table 13. The Main effect of Varieties and different types of fertilizer on unmarketable bulb yields of onion

| Varieties | Unmarketable bulb yield(t ha⁻¹) |
|---------------------------------------------|---------------------------------------------------|
| Nafis | 0.87 ^b |
| Nasik Red | 1.55 ^a |
| Red Creole | 0.66 ^c |
| Bombay Red | 0.88 ^b |
| LSD(0.05) | 0.17* |
| CV (%) | 23.38 |
| SE ± | 0.07 |
| Fertilizer type (kg ha⁻¹) | |
| NP | 1.01 ^a |
| NPS | 0.84 ^{ba} |
| NPSB | 0.8 ^b |
| NPSZn | 0.9 ^a |
| LSD(0.05) | 0.17ns |
| CV (%) | 23.38 |
| SE ± | 0.07 |

Means followed by the same letter in the same column and the same factor are not significantly different at (P < 0.05); LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.3.6. Total bulb yield (t ha⁻¹)

The analysis of variance revealed that the interaction effects of variety and fertilizer type had significant (p<0.01) influence on total bulb yield per hectare of onion (Appendix Table 10) The highest total bulb yield (32.25 t ha⁻¹) was observed in the interaction of

NPSB blended fertilizer type and Red Creole variety, which was statistically in parity with total bulb yield (27.81 t ha^{-1}) of Red Creole variety which received NPSZn. While the least total bulb yields (22.61 and 22.57 t ha^{-1}) was recorded in the NP and NPS treatment with Nasik Red varieties, respectively (Table 14).

This may be due to the increase in bulb size and bulb weight in response to nitrogen application that might have increased photosynthesis, and in turn, enhanced growth and expansion of vegetative growth as a whole, and eventually partitioning of markedly higher carbohydrates to the bulbs at maturity. This result is in agreement with the finding of Tibebu *et al.* (2014) who reported higher total bulb yields of onion in response to the application of nitrogen. Kokebe *et al.* (2007) also reported progressive increments in bulb yield of onion as a result of an increase in the rate of nitrogen. When onion matured, phosphorus translocation takes place into the bulb of the plant where high energy requirements are needed for the formation of bulbs because it is highly mobile in plants and translocated from old plant tissue to young actively growing areas.

Assefa *et al.* (2013) reported that combined effect of the contributions of nitrogen to chlorophyll, enzymes, and protein synthesis; as phosphorus is essential for root growth, phosphoproteins, and phospho-lipids that contribute for yield increment. The results are also consistent with the finding of Reddy *et al.* (2007) who reported that the application of 150 kg ha^{-1} nitrogen and 90 kg ha^{-1} phosphorus shown the maximum plant height, bulb diameter, and bulb yield of onion.

Sulfur is an important nutrient that increases the formation of vegetative structures for nutrient absorption and photosynthesis and increases the production of assimilates to fill the sinks, resulting in increased yield of onion. Zaman *et al.* (2011) reported a bulb yield increase in garlic with increasing sulfur level up to 45 kg ha^{-1} . Diriba *et al.* (2012) also reported that yield and yield attributes of garlic bulbs increased significantly with the increasing rates of nitrogen, phosphorus, and sulfur. Similarly, the higher total bulb yield could be due to boron that it translocates sugar and carbohydrates in different parts of the

plant body. Dake *et al.* (2015) reported improvement in growth, yield, and quality of onion with the application of boron.

Red Creole produced the higher total bulb yield (32.25 t ha⁻¹) and the smallest amount of total bulb yield (22.57 t ha⁻¹) was produced from Nasik Red variety (Table 14). The difference in bulb yield of onion varieties depends on variation in genotypes, climate and their interactions. This result is in line with the study of Benti *et al* (2011) who reported that the highest total bulb yield on the variety Red Creole, whereas the lowest yield by Nasik Red variety.

Table 14. Interaction effects of different types of fertilizer and Varieties on Total Marketable Yield of Onion

| Varieties | Fertilizer Type kg ha ⁻¹ | | | |
|------------|-------------------------------------|--------------------|--------------------|---------------------|
| | NP | NPS | NPSB | NPSZn |
| Nafis | 22.65 ^b | 23.21 ^b | 23.86 ^b | 25.51 ^b |
| Nasik Red | 22.61 ^b | 22.57 ^b | 24.02 ^b | 24.03 ^b |
| Red Creole | 24.21 ^b | 23.22 ^b | 32.25 ^a | 27.81 ^{ab} |
| Bombay Red | 24.16 ^b | 25.83 ^b | 26.36 ^b | 26.38 ^b |
| LSD (0.05) | 1.38** | | | |
| CV (%) | 6.67 | | | |
| SE ± | 0.55 | | | |

Means followed by the same letter(s) are not significantly different at (P < 0.05); LSD= least significance difference; CV= Coefficient of Variance; SE = Standard error.

4.4. Correlation Analysis on Growth, Yield Component and Yield of onion

Correlation coefficient (r) values, computed to determine the relationships between and within each pair of the characters, are presented in (Table 15). The correlation values showed apparent association of the variables with each other, and clearly indicated the magnitude and direction of the association and relationships. Results of the correlation analysis revealed that marketable bulb yield was positively and highly significantly ($P < 0.01$) correlated with plant height ($r = 0.68^{**}$), leaf length (0.69^{**}) number of leaves per plant ($r = 0.70^{**}$), bulb diameter ($r = 0.57^{**}$), bulb dry weight (0.69^{**}), average bulb fresh weight per plant ($r = 0.76^{**}$) and total bulb yield ($r = 0.79^{**}$) weakly and negatively correlated with unmarketable bulb yield ($r = 0.43$). The possible reason for the observed association between total bulb yield and those variables could be because increase in plant height and number of leaves produced higher photosynthesis, which in turn resulted in vigorous vegetative growth and those plants gave higher marketable and unmarketable bulb yield and as a result the total bulb yield of onion increased.

Table 15. Correlation Analysis on Growth, Yield Component and Yield of onion

| | PH | LL | LN | DM | BD | MBY | UNMB Y | TBY | AVBF W | BD W |
|-------|---------|--------|---------|---------|---------|--------|-----------|--------|-----------|---------|
| PH | 1.00 | | | | | | | | | |
| LL | 0.81** | 1.00 | | | | | | | | |
| LN | 0.63** | 0.75** | 1.00 | | | | | | | |
| DM | 0.68** | 0.58** | 0.47** | 1.00 | | | | | | |
| BD | 0.50** | 0.59** | 0.59** | 0.50** | 1.00 | | | | | |
| MBY | 0.68** | 0.69** | 0.7** | 0.51** | 0.57** | 1.00 | | | | |
| UNMBY | -0.34ns | -0.37* | -0.03ns | -0.25ns | -0.50** | -0.43* | 1.00 | | | |
| TBY | 0.67** | 0.7** | 0.68** | 0.6** | 0.61** | 0.79** | -0.20ns | 1.00 | | |
| AVBFW | 0.67** | 0.79** | 0.76** | 0.61** | 0.60** | 0.76** | -0.35ns | 0.76** | 1.00 | |
| BDW | 0.63** | 0.71** | 0.69** | 0.48** | 0.44* | 0.69** | -0.51** | 0.60** | 0.83** | 1.00 |

Where: *, ** and ns indicates that significant, highly significant and non-significant difference at probability levels of 5% and PH, LL, LN, DM, BD, MY, UMY, TY, AVBFW, and BDW= Plant height, Leaf Length, leaf number per plant, Days to maturity, Bulb diameter, Marketable yield, Unmarketable yield, Total yield, Average fresh weight and Bulb dry weight, respectively.

4.5. Economic Analysis of onion as influenced by different types of fertilizer and Varieties

4.5.1. Partial budget analysis

Partial budget is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. A partial budget is a way of calculating the total costs that vary and the net benefits of each treatment (CIMMYT, 1988). In this study, partial budget analysis was also employed by considering total variable cost and net benefit, dominated and non-dominated treatments using dominance analysis and marginal rate of return. The different costs of this experiment which include cost for different types of fertilizer, seed, and labor cost for different types of fertilizer application were used for this calculation. The purchasing price of different types of fertilizer and seeds was 15 Birr kg⁻¹ and 3600 Birr kg⁻¹ respectively. The cost for daily labor during the season was 120 Birr per day. The field price of onion during the harvesting season was 17.5birr kg⁻¹ and the cost of fertilizer transport was included. All the variable costs were subtracted from gross benefit to obtain net benefit. Accordingly, the highest net benefit (Birr 462412.00) was obtained from the treatment combination of NPSB fertilizer and Variety Red Creole followed by NPSZn fertilizer and Variety Red Creole with net benefit (Birr 391548.00). The lowest net benefit (Birr 302926.00) was recorded from plants with NP fertilizer and Variety Nasik Red indicated in (Table 16).

Table 16. Partial budget analysis of onion as influenced by different types of fertilizer and Varieties in Enemore during the 2020/2021

| Treatment combination | Marketable Bulb Yield (t ha ⁻¹) | Actual Marketable Yield (Kg ha ⁻¹) | Actual Marketable Yield - 10% (kg ha ⁻¹) | Adjusted Marketable Yield (kg ha ⁻¹) | Total Gross Return (Birr ha ⁻¹) | Cost of Fertilizer (Birr ha ⁻¹) | Cost of Labor to Apply different fertilizer (Birr ha ⁻¹) | Cost of Onion Seed (Birr ha ⁻¹) | Bulb Transport Cost (Birr ha ⁻¹) | Total Variable Cost (Birr ha ⁻¹) | Net Benefit (Birr ha ⁻¹) |
|-----------------------|---------------------------------------------|------------------------------------------------|------------------------------------------------------|--------------------------------------------------|---------------------------------------------|---------------------------------------------|----------------------------------------------------------------------|---------------------------------------------|----------------------------------------------|----------------------------------------------|--------------------------------------|
| NP*Naf | 21.64 | 21640 | 2164 | 19476 | 340830 | 4725 | 1020 | 12600 | 10711 | 29056 | 311774 |
| NP*NR | 21.06 | 21060 | 2106 | 18954 | 331695 | 4725 | 1020 | 12600 | 10424 | 28769 | 302926 |
| NP*RC | 23.61 | 23610 | 2361 | 21249 | 371857 | 4725 | 1020 | 12600 | 11686 | 30031 | 341826 |
| NP*BR | 23.26 | 23260 | 2326 | 20934 | 366345 | 4725 | 1020 | 12600 | 11513 | 29858 | 336487 |
| NPS*Naf | 22.41 | 22410 | 2241 | 20169 | 352957 | 6282 | 1375 | 12600 | 11092 | 31349 | 321608 |
| NPS*NR | 21.5 | 21500 | 2150 | 19350 | 338625 | 6282 | 1375 | 12600 | 10642 | 30899 | 307726 |
| NPS*RC | 22.55 | 22550 | 2255 | 20295 | 355162 | 6282 | 1375 | 12600 | 11162 | 31419 | 323743 |
| NPS*BR | 24.98 | 24980 | 2498 | 22482 | 393435 | 6282 | 1375 | 12600 | 12365 | 32622 | 360813 |
| NPSB*Na | 22.99 | 22990 | 2299 | 20691 | 362092 | 6282 | 1375 | 12600 | 11380 | 31637 | 330455 |
| NPSB*NR | 23.05 | 23050 | 2305 | 20745 | 363037 | 6282 | 1375 | 12600 | 11409 | 31666 | 331371 |
| NPSB*RC | 31.64 | 31640 | 3164 | 28476 | 498330 | 6282 | 1375 | 12600 | 15661 | 35918 | 462412 |
| NPSB*BR | 25.58 | 25580 | 2558 | 23022 | 402885 | 6282 | 1375 | 12600 | 12662 | 32919 | 369966 |
| NPSZn*Naf | 24.68 | 24680 | 2468 | 22212 | 388710 | 6477 | 1413 | 12600 | 12216 | 32706 | 356004 |
| NPSZn*NR | 23.03 | 23030 | 2303 | 20727 | 362722 | 6477 | 1413 | 12600 | 11399 | 31889 | 330833 |
| NPSZn*RC | 27.01 | 27010 | 2701 | 24309 | 425407 | 6477 | 1413 | 12600 | 13369 | 33859 | 391548 |
| NPSZn*BR | 25.36 | 25360 | 2536 | 22824 | 399420 | 6477 | 1413 | 12600 | 12553 | 33043 | 366377 |

Where: Nafis, NR=Nasik Red, RC=Red Creole, BR=Bombay Red

4.5.2. Marginal rate of return

Dominance analysis was carried out by listing the treatments in order of increasing the total variable costs to calculate marginal rate of return. According to CIMMYT (1988) any treatments that have net benefits less or equal to the previous treatment was denominated and discarded for further analysis. Therefore, the highest marginal rate of return (3441.7 %) was recorded from treatment combination of NPSB fertilizer and Variety Red Creole (Table 18).

Table 17. Dominance analysis of onion as influenced by different types of fertilizer and Varieties in Enemore during the 2020/20201

| Treatment Combination | Total Variable Cost (Birr ha ⁻¹) | Net Benefit (Birr ha ⁻¹) | Dominance |
|-----------------------|----------------------------------------------|--------------------------------------|-----------|
| NP*NR | 28769 | 302926 | |
| NP*Nafis | 29056 | 311774 | |
| NP*BR | 29858 | 336487 | |
| NP*RC | 30031 | 341826 | |
| NPS*NR | 30899 | 307726 | D |
| NPS*Nafis | 31349 | 321608 | D |
| NPS*RC | 31419 | 323743 | D |
| NPSB*Nafis | 31870 | 330222 | D |
| NPSB*NR | 31666 | 331371 | D |
| NPSZn*NR | 31899 | 330833 | D |
| NPS*BR | 32622 | 360813 | |
| NPSZn*Naf | 32706 | 356004 | D |
| NPSB*BR | 32919 | 369966 | |
| NPSZn*BR | 33043 | 366377 | D |
| NPSZn*RC | 33859 | 391548 | |
| NPSB*RC | 35918 | 462412 | |

Where: D= Dominated Nafis, NR=Nasik Red, RC=Red Creole, BR=Bombay Red

Table 18. Marginal rate of return (MRR) of onion as influenced by different types of fertilizer and Varieties in Enemore during the 2020/20201

| Treatment combination | Total variable cost (Birr/ha) | Net benefits (Birr/ha) | Marginal variable cost | Marginal net benefit | Marginal rate of return (%) |
|-----------------------|-------------------------------|------------------------|------------------------|----------------------|-----------------------------|
| NP*NR | 28769 | 302926 | | | |
| NP*Nafis | 29056 | 311774 | 287 | 8848 | 3082.9 |
| NP*BR | 29858 | 336487 | 802 | 24713 | 3081.4 |
| NP*RC | 30031 | 341826 | 173 | 5339 | 3086.1 |
| NPS*BR | 32622 | 360813 | 2591 | 18987 | 732.8 |
| NPSB*BR | 32919 | 369966 | 297 | 9153 | 3081.8 |
| NPSZn*RC | 33859 | 391548 | 940 | 21582 | 2295.95 |
| NPSB*RC | 35918 | 462412 | 2059 | 70864 | 3441.7 |

Where: Nafis, NR=Nasik Red, RC=Red Creole, BR=Bombay Red

5. CONCLUSION AND RECCOMENDATIONS

5.1. Conclusion

The experiment revealed that leaf number per plant, leaf length, average fresh bulb weight, bulb diameter; marketable bulb yield and total bulb yield were statistically significantly affected by the different types of fertilizers and varieties as well as their interactive effect.

The highest leaf number per plant, tallest leave length, and dry bulb weight was recorded by the combined treatment of the variety Red Creole and blended NPSB fertilizer application. The highest bulb diameter, bulb fresh weight, bulb dry weight, marketable yield and total bulb yield was recorded from the combined treatment of the variety Red Creole and blended NPSB and blended NPSZn fertilizer application.

The applications of blended NPSB and blended NPSZn fertilizers did not show statistically significant difference on their effect on both the yield and yield component parameters, Hence, the most economically attractive treatment combinations recommended for small-scale farmers were revealed to be of blended NPSB fertilizer in combination with variety Red Creole.

Results of the correlation analysis also revealed that plant height, leaf length, and number of leaves, bulb diameter and fresh weight onion bulbs and total bulb yield were highly significantly and positively correlated with the marketable bulb yield of onion.

In concurrence with results reported by CIMMYT, (1988), the partial budget analysis results also revealed that the highest net benefit of onion with acceptable level of marginal return was recorded from the combined treatment of NPSB fertilizer and variety Red Creole.

5.2. Recommendations

Based on the results of the present study, the combined application of NPSB blended fertilizer and variety Red Creole are recommended for onion producers in Enemore Woreda as well as other areas with similar agro-ecological conditions. As revealed by the partial budget analysis, this combined treatment can result in the highest net benefit increase of Birr 462412.00, with acceptable MRR (3441.7 %).

However, since, the study was conducted only for a single season and one location, further research recommended to be carried out at different seasons of the year and multiple potentially representative locations.

6. REFERENCES

- Abd El-Samad, E.H., Khalifa, R.Kh.M, Lashine, Z.A. and Shafeek, M.R. 2011. Influence of Urea Fertilization and Foliar Application of Some Micronutrients on Growth, Yield and Bulb Quality of Onion. *Australian Journal of Basic and Applied Sciences*, 5(5): 96-103.
- Abdissa Y, Pant L. Growth, bulb yield and quality of onion (*Allium cepa* L.) as influenced by nitrogen and phosphorus fertilization on vertisol. *Afr J Agric Res*. 2011; 6(14):3252-3258.
- Abraha Gebrekiros, Solomon Habtu and Yirga Weldu. 2015. Response of onion (*Allium cepa* L.) growth and yield to different combinations of N, P, S, Zn fertilizers and compost in northern Ethiopia. *International Journal of Science and Research*, 4(2), pp.985-989
- Acta Horticulture, 506:29-36 Anwar MN, Sarker JU, Rahman M, Islam MA and Begum M (2001) Response of onion to nitrogen, phosphorus, potassium, sulfur and zinc. *Bangladesh J Environ Sci*. 7: 68-72.
- Agumas B, Abeway A, Abebe D, *et al.* Response of irrigated onion (*Allium cepa* L.) to nitrogen and phosphorus fertilizers at Ribb and Koga irrigation schemes in Amhara region, North Western Ethiopia. *J AgricSci Soil Sci*. 2014; 4(5):95-00.
- Ahmed, M. K., Aditya, D. K. and Siddique, M. A. 1988. Effect of nitrogen and sulfur application on the growth and yield of onion cv. FaridpurBhatti, *Bangladesh Hort*. 16: 36-41.
- Al-Fraihat, A.H. 2009. Effect of different nitrogen and sulfur fertilizer levels on growth, yield and quality of onion (*Allium cepa* L.). *Jordan Journal of Agricultural Science*, 5:155-166.
- Ali MDS, Effects of micronutrients on growth, yield and quality of three varieties of summer onion M.Sc. Thesis, Department of Horticulture, Bangladesh Agricultural University, Mymensingh, 2013, 60
- Ali MK, Alam MN, Islam MS, *et al.* Effects of cow dung at different levels of phosphorus on growth, yield and quality seed production of onion. *J Agric Biol Sci*. 2018; 4(1):86-93.

- Alloway BJ, Zinc-the vital micronutrient for healthy, high-value crops, International Zinc Association, Brussels; 2001
- Alt, D., H. Ladebusch and O. Melzer.1999.Long-term trial with increasing amounts of phosphorus, potassium and magnesium applied to vegetable crops.
- Anwar *et al.*, 2001. Anwar MN, Sarker JU, Rahman M, Islam MA, and Begum M. 2001. Response of onion to nitrogen, phosphorus, potassium, sulfur and zinc, Bangladesh. *Journal of Environmental Science*, 7: 68-72.
- Assefa AG, Mesgina SH, Abrha YW, *et al.* Response of onion (*Allium cepa* L.) growth and yield to different combinations of N, P, S, Zn fertilizers and compost in Northern Ethiopia. *Int J Sci Res.* 2013; 2:985-989.
- Assefa AG, SH Mesgina and YW Abriha, 2015.Effect of inorganic and organic fertilizers on the growth and yield of garlic crop (*Allium sativum* L.) in Northern Ethiopia, *J AgricSci*, 7:80.
- Baloch, A.F. 1994. Vegetable crops, Horticulture, National Book Foundation, Islamabad, Pakistan, pp. 489-537
- Batjes, N.H.1997. A world data set of derived soil properties by FAO. UNESCO soil unit for global modeling. *Soil use manag.* 13:9-16.
- Bell AA (1981) Biochemical mechanisms of disease resistance, *Annu Rev Plant Physiol*, 32:21-81
Brewster JL (1994) Onions and other vegetable alliums, CAB, P 236
- Bhonde SR, DOD VN, Bharad SG, Gholap SV, JadhaoBJ. Seed production of onion as influenced by the application of growth regulators, *Indian J. Soils and Crops*, 1999; 9(1):78-79.
- Bielecki, R. L.1973. Phosphate pools, phosphate transport, phosphate availability. *Ann Rev Plant Physiology*, 24:225-252.
- Bloem E, Haneklaus S, Schnug E, *et al.* Influence of nitrogen and sulfur fertilization on the alliin content of onions and garlic. *J Plant Nutr.* 2005; 27:1827-839.

- Bloem, E.S., Haneklaus and Schnug, E. 2004. Influence of nitrogen and sulfur fertilization on the alliin content of onions and garlic. *J. of Plant Nutrition*, 27: 1827-1839.
- Brady, N.C. and R. R. Weil, 2002. *The Nature and Properties of Soils*, Thirteenth Edition Pearson Education Asia, Delhi, India, 960P
- Bremner JM, Mulvaney CS.1982. Nitrogen- Total. In: A.L. page, *methods of soil analysis*, American Society of Agronomy Inc., American Society of Soil science Inc., Madison pp. 595-624.
- Brewster J. L. and Butler H. A. 1999. Effects of nitrogen supply on bulb development in onion (*Allium cepa*L.). *Journal of Experimental Botany*.40:1155-1162.
- Brewster J.L, Robinowitch HD. 1989. Onion and allied crops, vol. III. *Biochemistry, Food science and Minor Crops*; 3:1-298
- Brewster JL. 1994. *Onions and Other Vegetable Alliums*, CABI Publishing, Wallingford, UK, .p321
- Brosnan, J.T., and M.E, Brosnan. 2006. The Sulfur-Containing Amino Acids: An Overview. *J. Nutr.* 136:16365-16405.
- Cakmak I. 2007. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant and Soil*; 302:1-17
- CSA (Central Statistical Authority). 2018. *Report on Area and Production of Private Peasant Holdings Statistical Bulletin, Vol 1 Addis Ababa, Ethiopia.*
- Desalenge Lemma. And AkliluShimelis.2003. "Article title", *Research Experiences in Onion Production*, EARO Ethiopian Agricultural Research Organization, and Research Report No 55. No ISBN.
- EARO (Ethiopian Agricultural Research Organization).2004.*Directory of Released Crop Varieties and their Management*, Addis Ababa, Ethiopia
- EIAR (Ethiopian Institution of Agricultural Research). 2012. *Directory of released crop varieties and their recommended cultural practices*. Addis Ababa, Ethiopia

- El-Shafie, Fattma S. and El-Gamaily, E. 2002. Effect of organic manure, sulphur and microelements on growth, bulb yield, storability and chemical composition of onion plants, *Minufiya J. Agric. Res.*, 27: 407-424.
- Ethio-SIS (Ethiopian Soil Information System). 2014. Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia. Ministry of Agriculture and Agricultural Transformation Agency: 92. www.ata.gov.et
- Fairhurst, T., R. Lefroy, E. Mutert and N. Batijes .1999. The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. *Agro forestry Forum* 9: 2-8.
- FAO (Food and Agricultural Organization of the United Nations) .2006. Guidelines for soil profile description. Soil Resources, Management and Conservation Service, Land and Water Development Division, Rome
- FAO (Food and Agriculture Organization of the United National). 2017. Production year book, Food and Agriculture.
- FAOSTAT (Food and Agricultural Organization of the United Nations Statistics). 2014. Food and Agriculture Data of the United Nations Organization <http://www.fao.org/faostat/en/#home> (accessed April 2016)
- Ghaffoor A, Jilani G. and Khaliq K. 2013. Effect of different NPK levels on the growth and yield of three onion (*Allium cepa* L.) varieties. *Asian J Plant Sci.* 2:342-346.
- Goldman I.L. 2011. Molecular breeding of healthy vegetables. *EMBO Rep.* 12:96-02.
- Gomez, K.A and Gomez, A.A. 1984. Statistical procedures for agricultural research. 2nd Edition, an International Rice Research Institute Book, Wiley-Inter science Publication, John Wiley & Sons, New York, 390.
- Greenwood, D.J., D.A. Stone and T.V. Karpinets. 2001. Dynamic model for the effects of soil P and fertilizer P on crop growth, P uptake and soil P in arable cropping: Experimental test of the model for field vegetables, *Annals of Botany*, 88: 293- 306.

- Griffiths, G., L. T., Trueman, B., Crowther, B., Thomas, B. Smith. 2002. Onions- A global benefit to health. John Wiley and Sons, Ltd
- Grubben, J.H. and D.A. Denton. 2004, Plant resources of tropical Africa, PROTA Foundation, Wageningen; Back huys, Leiden; CTA, Wageningen.
- GueshTekle. 2015. Growth, yield, and quality of onion (*Allium cepa*L.) as influenced by intrarow spacing and nitrogen fertilizer levels in central zone of Tigray, Northern Ethiopia, M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia
- Gustfson AA. 2010. Hand book of fertilizers, their source, makeup, effect and use. Agro bios, India:77-86.
- Hamasaki, R. Valenzuela, H. and Shimabuku, R. 1999. *Bulb Onion Production in Hawaii*, College of Tropical Agriculture and Human Resources (CTAHR), Hawaii, USA
- Haneklaus, S., E. Bloem, E. Schnug, L.J. de Kok, and I. Stulen. 2006. Sulfur. *In*: Barker, A.V., and D.J. Pilbeam (eds.). Handbook of Plant Nutrition (2nd edition), CRC Press, Boca Raton, FL, USA, p. 183-215
- Hanelt, P. 1990. Taxonomy, evolution and history. *In* Rabinowitch, H.D. and Brewster, J.L., eds: Onion and allied crops, Vol. 1. Botany, Physiology and Genetics, pp. 1-26., CRC Press, Boca Raton, Florida.
- Hinsinger, P. 2001. Bioavailability of soil inorganic P in the rhizosphere as affected by root- induced chemical changes: a review. *Plant and soil*, 237: 173-195
- Jaggi R, Dixit S. 1999. Onion (*Allium cepa* L.) responses to sulfur in representative vegetable growing soils of Kangra Valley of Himachal Pradesh. *Ind J Agric Sci* 69:289-291
- Karim S.M.R. and N.R. Ibrahim. 2013. Effect of planting time, day length, soil pH and soil moisture on onion, *International Journal of Biological Pharmacia Applied Science*.2: 807
- Kokobe W, Derbew B and Adugna D. 2007. Effect of farmyard manure and nitrogen fertilizer rates on growth, yield and components of onion (*Allium cepa* L.) at Jimma, South West Ethiopia. *As J Plant Sci.*: 1-6.

- Kumar A, Singh O (1995) Effect of sulfur deficiency on plant growth and yield of onion, *Ind J Agric Res* 29:127- 130
- Lemma Dessalegn and Herath E. 1994. *Agronomic studies on allium*. In: Horticulture research and development in Ethiopia; Proceedings of National Horticultural Workshop of Ethiopia, 2nd, Dec 1-3, 1992. Institute of Agricultural Research, Addis Ababa, Ethiopia, Pp. 152-162.
- Lemma Dessalegn and Shimeles Aklilu. 2003, Research Experience in Onion Production .Research Report Number 55, EARO, Addis Ababa, Ethiopia
- Lemma Dessalegn, Shimeles Aklilu, Selamawit Ketema and Chimdo Anchela, 2006, *the Vegetable Seed Sector in Ethiopia: Current Status and Future Prospects*. EHSS, Proceedings of the Inaugural and Third National Horticultural Workshop, Ethiopia, Volume I. 103-109.
- Lemma Dessalegn. 1998. Seed production guideline for tomatoes, onion and hot pepper Institute of Agricultural Research (IAR), 22p
- Lemma Dessalegn. 2004. Onion Production Pamphlet (Amharic version), EARO, Melkassa Research Center
- Malik, M. N. 2000. Horticulture, Biotech Books, Delhi, 586p
- Malik, M.N. 1994. *Bulb crops, Onion*. In Horticulture, pp. 500-501. National Book Foundation Islamabad Pakistan
- Manna D. 2014. Growth, yield and bulb quality of onion (*Allium cepa* L.) in response to foliar application of boron and zinc, *SAARC J Agric*, 11: 149-153
- Manna D. 2014. Growth, yield and bulb quality of onion (*Allium cepa* L.) in response to foliar application of boron and zinc. *J Plant Nutri.*: 39.
- Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd ed. Academic press. London. 196 p
- Maurya AN, Lal S. 1975. Boron in relation to the growth and development of onion (*Allium cepa* L.), *Bangladesh Hort.*: 3(1):1-7

- McGrath, S.P, and F.J. Zhao. 1996. Sulfur Uptake, Yield Response and the Interactions between N and S in Winter Oilseed Rape (*Brassica napus*), J. Agric. Scie. 126:53-62.
- Melkamu Alemayehu, Fentahun Tesafa, Solomon Bizuayehu and Belayneh Ayele.2015.Amhara Region horticultural development strategy (2015-2020), Agro BIG and ANRS BoA, Bahir Dar, Ethiopia, 127
- Mirete D. Dechassa N. 2015.Influence of mineral nitrogen and phosphorus fertilizer rates on growth, yield components and bulb yield of onion (*Allium cepa* var. *cepa*) at Kobo, MSc Thesis presented to the school of Haramaya University, Ethiopia.
- MoARD (Ministry of Agriculture and Rural Development). 2005. Irrigation Development Package Manual, Amharic version
- MoARD (Ministry of Agriculture and Rural Development).2005, Irrigation development package manual (Amharic version), Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia
- MoARD (Ministry of Agriculture and Rural Development).2009.Rural Capacity Building project, Course for Training of trainers on improved horticultural crop technologies, pp. 5-19
- MoARD (Ministry of Agriculture and Rural Development).2010. *Crop variety registers* Ministry of Agriculture and Rural Development, Issue no.13, Addis Ababa
- Morberg JP. 2000. *Soil and plant analysis Manual*, Royal Veterinary and Agricultural University, Chemistry Department, Copenhagen, Denmark 133 p
- Murphy, H.F.1959. A Report on Fertility Status of Some Soils of Ethiopia, HSIU/College of Agric, Alemaya Experiment Station, Bull. No. 1
- Nasreen S, Haque M, Hossain M, Farid A. 2007.Nutrient uptake and yield of onion as influenced by nitrogen and sulfur fertilization. Bangladesh J Agric Res.: 32(3): 413-20.
- Nasreen S, Huq SMI. 2005. Effect of sulfur fertilization on yield, sulfur content and uptake by onion. Ind J Agri Res, 39(2):122-27.

- Nasreen, S., Haque, M. M., Hossain, M. A. & Farid, A. T. M. Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. *Bangladesh J. Agric. Res.* **32**(3), 413–420 (2007).
- Nigatu M. 2016. Assessment of Onion production practices and effects of N: P₂O₅: S fertilizers rates on yield and yield components of onion (*Allium cepa* L.). MSc Thesis presented to the School of Graduate Studies of Bahir Dar University College of Agriculture and Environmental Sciences Bahir Dar, Ethiopia.
- Nikus O. and Fikre Mulugeta. 2010. *Onion Seed Production Techniques: A Manual for extension agents and seed producers*, FAOCDMDP, Asella, Ethiopia.
- Norman, J.C. 1992. *Tropical Vegetable Crops*. Aurher Stockwell Ltd. UK.
- Okalebo JR, Gathua KW and Woomer PL. 2002. Laboratory methods of soil and plant analyses: a working manual, 2nd ed. TSBF-CIAT and SACRED Africa, Nairobi, Kenya.
- Opara, LU. 2003. Onions: Post-Harvest Operation. Massey University, AGST/FAO: Danilo Mejia: Palmerston North, New Zealand, pp: 1-16.
- Pant H.K. and K.R. Reddy .2003. Potential internal loading of phosphorus in a wetlands constructed in agricultural land water research, *37*: 965-972.
- Pedler JF, Parker DR, Crowley DE. 2000. Zinc deficiency-induced phytosiderophore release by the Triticaceae is not consistently expressed in solution culture. *Planta*: 211:120-126
- Purseglove, J.W. 1985. *Tropical crops Monocotyledons*. Longman Singapore Publishers, PTC, Ltd. pp 271-279.
- Randle WM, Ketter CA .1998. Pungency assessment in onions. Proceedings of the 19 workshop conference of the Association for Biology Laboratory Education (ABLE). pp. 177-196, <http://www.zoo.utoronto.ca/able/volumes/copyright.htm>
- Rao VJM, Deshpande R. 1971. Effect of micronutrients (copper and boron) on the growth and yield of onion (*Allium cepa* L.), *Indian J. Agril, Res.*: 5(4):257-260.
- Rice, R.P.; L.W. Rice and H.D. Tindall. 1993. Fruit and vegetable production in warm climates The Macmillan press Ltd. London and Basingstoke.

- Richardson, H. L. 1968. *The Use of Fertilizers: The Soil Resources of Tropical Africa* Moss, R. P. Cambridge University Press. P. 138
- Robinowith, H.D., and L. Currah. 2002. *Alliums Crop Sciences: Recent Advances*. CABI Publishing International, London UK, 515
- Rubatzky, V.E and Yamagunchi, M. 1997. *World Vegetables, Principles, Production, and Nutritive Value 2nd edition*, International Thomson publishing, 804 p
- Shafeek, M.R., S. Faten, Abd El-Al and Aisha, H. Ali. 2004. The productivity of broad bean plant as affected by chemical and/or natural phosphorus with different biofertilizer. *J. Agric.Sci. Mansoura Univ.* 29: 2727-2740.
- Simon, P.W. 1992. *Onion Improvement Newsletter for 1991*. Dept of Horticulture, University of Wisconsin, Madison, Wisconsin, USA
- Singh, J.V., A. Kumar and C.Singh. 1998. Studies on the storage of onion (*Allium cepa*L.) as affected by different levels of phosphorus. *Indian Journal Agricultural Research*, 32:5156.
- Sisay Habte. 2004. *Fresh Fruits and Vegetables Production and Marketing Study*. Ethiopian Export Promotion Agency, Addis Ababa, Ethiopia,
- Sorensen, J.N. and Grevsen, K. 2001. Sprouting in bulb onions (*Allium cepa*L.) as influenced by nitrogen and water stress. *Journal of Horticultural Science and Biotechnology*, 76:501-506.
- Southern Agricultural Research institute (2016). *Agricultural Growth program 2crop Research progress Report (2016/17)* Hawassa.
- Steel RGD, Torrie JH. 1990. *Principles and Procedures of Statistics* McGraw-Hill Book Co, New York
- TegbewW. 2011. *Yield and yield components of onion (Allium cepa var. cepa) varieties as influenced by population density at BirSheleko, North-Western Ethiopia*. MSc Thesis presented to the school of graduate to Haramaya University, Haramaya, Ethiopia.

- Tesfalgna JA and Mohammed W. 2015. Response of onion (*Allium cepa* L.) varieties to intra-row spacing at Kobo, Northern Ethiopia. MSc Thesis presented to the school of graduate to Haramaya University, Haramaya, Ethiopia.
- Tindall, H.D. 1983. Vegetables in the tropics .New Delhi, India, CBS Publishers and Distributors:p 533
- Tisdale LS, Nelson Beaton LW. 1984. Havlin Soil Fertility and Fertilizers, Prentice Hall of India, 5th edition: 3:19
- Trivedi AP and Dhumal KN. 2013. Effect of soil and foliar applications of zinc and iron on the yield and quality of onion (*Allium cepa* L.), Bangladesh Journal of Agricultural Research: 38(1):41-48.
- Uzma A, Sayed H and Syed Z. 2016. Interactive effect of phosphorus and zinc on the growth, yield and nutrient uptake of garlic (*Allium sativum* L.) variety Gulabi. Asian J Agri Food: 04.
- Warade, S.D., S.B. Desale and K.G. Shinde.1996.Effects of organic inorganic and bio fertilizers on yield of onion bulbs cv.B-780.Journal of Maharashtra Agricultural Universities, Publ. 0(3): 467-468.
- Zaidi, A. and Sr. K.Mohammad.2005.Co-Inoculation effects of phosphate, solubilizing, microorganisms and *glomus fasciculatum* on green gram-*Bradyrhizobium* Symbiosis. Turk J. Agri, for, 30: 223-230
- Zelege A and E Derso. 2015. Production and management of major vegetable crops in Ethiopia pp: 32-51. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia
- Zohary, D. and M. Hopf.2000.Domestication of plants in the old world, 3rd ed. Oxford University press, pp.197-198.

7. APPENDIXES

7.1. Appendix Tables

Appendix Table 1. Mean squares from analysis of variance (ANOVA) for days to maturity, plant height, leaf length and Leaf number of onion as influenced by different types of fertilizer and Varieties

| Source of variation | Mean squares | | | | |
|---------------------|--------------|----------|----------|----------|---------|
| | DF | DM | PH | LL | NL |
| Replication | 2 | 463.18** | 8.62 | 2.11 | 1.26 |
| Variety | 3 | 451.77** | 127.42** | 263.69** | 32.45** |
| Fertilizer | 3 | 580.72** | 546.02** | 431.46** | 11.90** |
| Variety*Fertilizer | 9 | 6.27ns | 17.00ns | 67.31** | 5.61** |
| Error | 30 | 5.78 | 18.18 | 8.38 | 1.58 |
| Total | 47 | | | | |
| CV (%) | | 2.14 | 7.76 | 6.51 | 14.09 |

Where: *DF = degrees of freedom, NS, * and ** implies non-significant, Significant and highly significance differences at 5% level of probability, respectively*

Appendix Table 2. Mean squares from analysis of variance (ANOVA) for bulb diameter, average fresh bulb weight and bulb dry weight of onion as influenced by different types of fertilizer and Varieties

| Source of variation | Mean squares | | | |
|----------------------|--------------|--------|-----------|---------|
| | DF | BD | AVBW | BDW |
| Replication | 2 | 0.043 | 5.97 | 0.43 |
| Varieties | 3 | 1.30** | 1749.25** | 41.57** |
| Fertilizer | 3 | 0.43** | 560.81** | 23.74** |
| Varieties*Fertilizer | 9 | 0.30** | 163.43** | 4.32ns |
| Error | 30 | 0.092 | 8.13 | 2.45 |
| Total | 47 | | | |
| CV (%) | | 5.67 | 4.00 | 16.3 |

Where: *DF = degrees of freedom, NS, * and ** implies non-significant, Significant and highly significance differences*

Appendix Table 3. Mean squares from analysis of variance (ANOVA) for marketable bulb yield, unmarketable bulb yield and total bulb yield of onion as influenced by different types of fertilizer and Varieties

| Source of variation | Mean squares | | | |
|----------------------|--------------|---------|---------|---------|
| | DF | MBY | UNMBY | TBY |
| Replication | 2 | 3.97 | 0.047 | 2.11 |
| Varieties | 3 | 40.01** | 0.45** | 32.89** |
| Fertilizer | 3 | 32.91** | 0.099ns | 30.78** |
| Varieties*Fertilizer | 9 | 9.64** | 0.067ns | 9.82** |
| Error | 30 | 2.74 | 0.043 | 2.76 |
| Total | 47 | | | |
| CV(%) | | 6.89 | 23.38 | 6.67 |

Where: *DF* = degrees of freedom, *NS*, * and ** implies non-significant, Significant and highly significance differences at 5% level of probability, respectively.

Appendix Table 4. Partial budget analysis of onion as influenced by different types of fertilizer and Varieties in Enemore during the 2020/2021

| Treatment combination | Marketale Bulb Yield (t ha ⁻¹) | Actual Marketale Yield (Kg ha ⁻¹) | Actual Marketale Yield - 10% (kg ha ⁻¹) | Adjusted Marketale Yield (kg ha ⁻¹) | Total Gross Return (Birr ha ⁻¹) | Cost of Fertilizer (Birr ha ⁻¹) | Cost of Labor to Apply different fertilizer (Birr ha ⁻¹) | Cost of Onion Seed (Birr ha ⁻¹) | Bulb Transport Cost (Birr ha ⁻¹) | Total Variable Cost (Birr ha ⁻¹) | Net Benefit (Birr ha ⁻¹) |
|-----------------------|--------------------------------------------|-----------------------------------------------|-----------------------------------------------------|-------------------------------------------------|---------------------------------------------|---------------------------------------------|----------------------------------------------------------------------|---------------------------------------------|----------------------------------------------|----------------------------------------------|--------------------------------------|
| 200*Naf | 21.64 | 21640 | 2164 | 19476 | 340830 | 4725 | 1020 | 12600 | 10711 | 29056 | 311774 |
| 200*NR | 21.06 | 21060 | 2106 | 18954 | 331695 | 4725 | 1020 | 12600 | 10424 | 28769 | 302926 |
| 200*RC | 23.61 | 23610 | 2361 | 21249 | 371857 | 4725 | 1020 | 12600 | 11686 | 30031 | 341826 |
| 200*BR | 23.26 | 23260 | 2326 | 20934 | 366345 | 4725 | 1020 | 12600 | 11513 | 29858 | 336487 |
| 244*Naf | 22.41 | 22410 | 2241 | 20169 | 352957 | 6282 | 1375 | 12600 | 11092 | 31349 | 321608 |
| 244*NR | 21.5 | 21500 | 2150 | 19350 | 338625 | 6282 | 1375 | 12600 | 10642 | 30899 | 307726 |
| 244*RC | 22.55 | 22550 | 2255 | 20295 | 355162 | 6282 | 1375 | 12600 | 11162 | 31419 | 323743 |
| 244*BR | 24.98 | 24980 | 2498 | 22482 | 393435 | 6282 | 1375 | 12600 | 12365 | 32622 | 360813 |
| 244*Naf | 22.99 | 22990 | 2299 | 20691 | 362092 | 6282 | 1375 | 12600 | 11380 | 31637 | 330455 |
| 244*NR | 23.05 | 23050 | 2305 | 20745 | 363037 | 6282 | 1375 | 12600 | 11409 | 31666 | 331371 |
| 244*RC | 31.64 | 31640 | 3164 | 28476 | 498330 | 6282 | 1375 | 12600 | 15661 | 35918 | 462412 |
| 244*BR | 25.58 | 25580 | 2558 | 23022 | 402885 | 6282 | 1375 | 12600 | 12662 | 32919 | 369966 |
| 257*Naf | 24.68 | 24680 | 2468 | 22212 | 388710 | 6477 | 1413 | 12600 | 12216 | 32706 | 356004 |
| 257*NR | 23.03 | 23030 | 2303 | 20727 | 362722 | 6477 | 1413 | 12600 | 11399 | 31889 | 330833 |
| 257*RC | 27.01 | 27010 | 2701 | 24309 | 425407 | 6477 | 1413 | 12600 | 13369 | 33859 | 391548 |
| 257*BR | 25.36 | 25360 | 2536 | 22824 | 399420 | 6477 | 1413 | 12600 | 12553 | 33043 | 366377 |

Appendix Table 5. Laboratory analysis results of the soil physicochemical properties of the experimental/study site

| Soil Physical Properties | Value | Rating | Range | References |
|------------------------------|-----------------|---------------|-----------|-----------------------------|
| Sand (%) | 20 | Moderate | 10.0-25.0 | Hazelton and Murphy (2007) |
| Silt (%) | 46 | Low | >50.0 | Hazelton and Murphy (2007) |
| Clay (%) | 34 | High | 10.0-25.0 | Hazelton and Murphy, (2007) |
| Textural class | Silty clay loam | | - | Day, 1965/Hydrometer |
| Soil Chemical Properties | | | | |
| pH (1:2.5 H ₂ O) | 6.8 | Slightly acid | 5.5-7.5 | Chopra and Kanwar, 1976 |
| TN (%) | 0.121 | Low | 0.1- 0.2 | Kjeldahl method,(1973) |
| OC (%) | 1.404 | Low | 0.6-1.5 | Walkley and Black,(1934) |
| CEC cmol(+) kg ⁻¹ | 63.25 | Medium | 15-25 | Lendon,1991 |
| Av. Phosphorus(ppm) | 4.68 | Very low | 7 | Hazelton and Murphy (2016) |
| Av. Sulfur (ppm) | 17.83 | Medium | 5-20 | Horneck et al., (2011) |
| Av. Zinc (ppm) | 1.3 | Low | 1.1-1.5 | Benton (2003) |
| Av. Boron (ppm) | 0.08 | Low | 0.3-1 | Benton, (2003) |

Where: CEC=Cation exchange capacity, OC=Organic carbon, OM= Organic Matter, TN=Total nitrogen, Av. = Available= P = phosphorus, Av. = Available, S = sulfur, Av. = Available Zn = zinc=boron, ppm = parts per million.

7.2. APPENDIX PLATES (PHOTOS)



Appendix Plate 1: Partial view of the experimental area, Enomore Woreda Agric. Office,
Terhog Kebele Farmers Training Center (FTC) Nursery Site,



Appendix Plate 2: Pre-transplanting land preparation of the experimental area



Appendix Plate 3: Mulching of onion seedbeds



Appendix Plate 4: Post-transplanting management and mid-term evaluation of the experiment



Appendix Plate 5: Harvesting and sample grading of onion bulbs

8. BIOGRAPHIC SKETCH

The author was born on April 14, 1978 in Enemore ena Ener district, Gurage zone, and Southern regional state. He attended his primary school education in Gunchire Junior School from 1984 to 1992. He attends high school at Gunchire senior secondary school from 1993 to 1994. In 1999, he joined Wolaita ATVET College of agriculture and graduated on July 25, 2001 with Diploma in plant science. After his graduation, he was employed by Gurage zone, Enemore and Ener Woreda bureau of agriculture and rural development as an extension agent and supervisor from 2002 to 2006.

In 2005, he joined Dilla University, College of Agriculture and Natural resources in summer program and attended his undergraduate study and graduated on November 11, 2009 with BSc degree in plant science. After graduation he worked in Gurage zone, Enemor ena Ener Woreda bureau of agriculture and rural development head office. In 2012/13 academic year, he joined Wolkite University, College of Agriculture and Natural resources graduate studies to pursue his MSc in Horticulture filed of specialization.