



**RESPONSE OF BARLEY (*Hordeum vulgare* L.) GENOTYPES TO
INORGANIC FERTILIZER TYPES UNDER ACIDIC SOIL OF
HAGERESELAM, SOUTHERN ETHIOPIA**

M.SC THESIS

HAILU HAMESO

HAWASSA UNIVERSITY

COLLEGE OF AGRICULTURE

HAWASSA, ETHIOPIA

JULY 2020

**Response of Barley (*Hordeum Vulgar* L) Genotypes to inorganic Fertilizer
Types under Acidic Soil of Hagereslam, Southern Ethiopia**

HAILU HAMESO

MAJOR ADVISOR: WALELIGN WORKU (PROFESSOR)

CO-ADVISOR: TEWODROS AYALEW (ASSOCIATE PROFESSOR)

A Thesis Submitted To the School of Plant and Horticulture Science

HAWASSA UNIVERSITY

College of Agriculture

In Partial Fulfillment of the Requirements for the Degree of Master of Science

In agriculture (specialization: Agronomy)

Hawassa, Ethiopia

July 2020

HAWASSA UNIVERSITY

ADVISORS APPROVAL SHEET -2

(Submission Sheet -2)

We, the undersigned members of the board of the examiners of the final open defense by Hailu Hameso have read and evaluated his thesis entitled. **Response of Barley (*Hordeum vulgare* L.) Genotypes to Inorganic Fertilizers Types under Acidic Soil of Hagerselam, Southern Ethiopia** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in plant sciences with specialization in **Agronomy**.

----- Name of chairperson	----- Signature	----- Date
Walegn Worku (Professor)	-----	-----
Name of Major Advisor:	Signature	Date
-----	-----	-----
Name of Internal Examiner	Signature	Date
-----	-----	-----
Name of External Examiner	Signature	Date
-----	-----	-----
SGS	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the school of Graduate Studies (SGS) through the school graduate committee (SGS) of the candidate's school.

DEDICATION

This research work is dedicate to whom every individual who serve their country honestly by taking every requirement sacrifice and giving priority for client society which suffers from every bias service, instead of their own benefits and recognition; to whom they spent their life time for the wellbeing of our world in all aspect.

STATEMENT OF THE AUTHOR

By my signature below, I declare that this thesis is my genuine work, and that all sources of materials used for this thesis have been profoundly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Master of Science in Agriculture specialization of agronomy at Hawassa University college of Agriculture and it is placed at the University library to be made available for users under the rule of the library.

I intensely declare that this thesis is not submitted to any other institution any where for the award of any academic degree, diploma or certificate. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his/her judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author and advisors of this thesis.

Name: HAILU HAMESO

Signature

Place: college of Agriculture, Hawassa University, Hawassa

Date of submission

ACKNOWLEDGEMENTS

Above all, I am forever grateful to the almighty God for His blessings and keeping my spirits up even in the most difficult times. My deepest thanks goes to Professor Walelign Worku, my major research advisor, for his sustained and educative guidance, unreserved advice, suggestions and collaboration. His constructive comments, exemplary supports and professional involvement immensely contributed to the accomplishment from proposal preparation till complete write-up of this thesis of the research work. I also extend my heart-felt thanks to Associate Professor Tewodros Ayalew, my co-advisor, for his careful scrutiny during the preparation of the proposal, important comments during the field research, and for reviewing the thesis.

I would like to thank Hawassa University for creating a learning environment in terms of training. I would like to acknowledge Dr, Hewan Demissie the coordinator of thematic research project: Enhancing Food Security through improved productivity of Barley in southern Ethiopia for funding the M.Sc thesis research grant. I wish to express my thanks to Hawassa soil testing laboratory for their cooperation during soil laboratory analysis. I would like to express my great attitude also to my friends, colleagues, and all other people who helped me in one way or the other in completing this research work.

TABLE CONTENTS

DEDICATION	i
STATEMENT OF THE AUTHOR	ii
ACKNOWLEDGEMENTS	iii
TABLE CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF APPENDICES	ix
LIST OF FIGURES IN THE APPENDIX.....	x
LIST OF ACRONYMS AND ABBREVIATIONS.....	xi
ABSTRACT.....	xii
1. INTRODUCTION	1
1.1. Background and Justification.....	1
1.2. Statement of the Problem.....	4
1.3. Objectives	5
1.3.1. General objective	5
1.3.2. Specific objectives	5
1.4 Hypothesis.....	5
2. LITERATURE REVIEW	6
2.1. Distribution and Importance of Barley	6
2.2. Cultivation of Barley in Ethiopia	7
2.3. Effect of Inorganic Fertilizer on Growth, Yield and Yield Components of Barley under Acidic Soil Conditions.....	8
2.3.1. Phosphorus Fertilizer under Acidic Soil Conditions.....	8
2.3.2. Response of Barley to Nitrogen under Acidic Soil Conditions	10
2.3.4. Response of Barley to Sulfur	12
2.3.5. Response of Barley to Boron	13
2.4. Effect of Soil Acidity on Nutrient Availability and Crop Yield.....	14
2.5. Soil Acidity Management	15
2.5.1. Using Acid Tolerant Crop Varieties	15
2.6. Genotypic Differences in Response to Fertilizer Application under Acidic Soil	16

2.7. Mechanisms of Barley Tolerate to Acidic Soil	16
3. MATERIALS AND METHODS	18
3.1. Description of Study Site	18
3.2. Treatments, Experimental Design and Procedures	19
3.3. Pre-Sowing and Post Harvest Soil Analysis	20
3.4. Data Collection and Analysis.....	21
3.5 Economic Analysis of Treatment Effects	22
3.6. Statistical Analyses	23
4. RESULTS AND DISCUSSIONS	24
4.1. Physico-Chemical Properties of the Study Soil	24
4.1.1. Soil Physico-Chemical Properties of the Experimental Site before Sowing.....	24
4.1.2. Soil Physico-Chemical Properties of the Experimental Site after Harvesting	26
4.2. Crop Phenology and Plant Height.....	28
4.2.1. Days to Emergence and Heading	28
4.2.2. Effects on Days to Physiological Maturity	30
4.2.3. Plant Height	31
4.3. Yield Components Affected by Barley Genotypes and Inorganic Fertilizer Types.....	32
4.3.1. Number of Effective Tillers	32
4.3.2. Spike Length	34
4.3.3 Number of Grain per Spike	35
4.3.4. Thousand Grain Weight	36
4.4 Yield Traits Affected by Barley Genotypes and Inorganic Fertilizer Types	37
4.4.1 Above Ground Biomass	37
4.4.2. Grain Yield.....	39
4.4. 3. Straw Yield	41
4.4.4. Harvest Index	42
4.5. Grain Yield Response Index	43
4.6 Correlations.....	45
4.7. Economic Analysis	47
5. SUMMARY AND CONCLUSION.....	50
6. REFERENCES	53
7. APPENDICES	76

7.1. Tables in Appendices	76
7.2: Figures in Appendices	80
BIOGRAPHICAL SKETCH	84

LIST OF TABLES

TABLE	PAGE
1:Combinations of The Treatments under The Study.....	20
2:Fertilizer Types and Their Nutrient Contents For used to The Experiment.	20
3:Soil Physic- Chemical Characteristics of The Experimental Field before Sowing	26
4:Effect of Different Types of Inorganic Fertilizers and Barley Genotypes Combinations on Soil Chemical Properties under Acidic Soil.....	28
5:Main Effects of Inorganic Fertilizers and Barley Genotypes on Days of Emergence and Heading under Acidic Soil.....	30
6:Interaction Effect of Barley Genotypes With The Types of Inorganic Fertilizers on Physiological Maturity.....	31
7:Interaction Effect of Barley Genotypes and Types of Inorganic Fertilizers on Plant Height and Number of Effective Tillers.....	34
8:Effect of Inorganic Fertilizer Types and Barley Genotypes on Spike Length (SL), Number of Grain Per Spike (NGS) and Thousand Grain Weight (TGW) of Barley Genotypes.....	37
9:Main Effect of Barley Genotypes and Types of Inorganic Fertilizers on Straw Yield and Harvest Index under Acidic Soil.....	43
10:Correlation Coefficients Between Mean Agronomic Traits of Barley Genotypes Grown With Types of Inorganic Fertilizers under Acidic Soil at Hagerselam.....	46
11:Partial Budgets and Dominance Analysis of Barley Genotypes Yield Influenced By Types of Inorganic Fertilizer Application.....	48
12:Marginal Analysis of Barley Genotypes Yield Influenced With Types of Inorganic Fertilizers.	49

LIST OF FIGURES

FIGURE	PAGE
1:Geographical Location Map f oThe Study area.....	18
2:Interaction Effects of Barely Genotypes and Inorganic Fertilizer Application With Regard to Above Ground Biomass Yield.....	39
3:Interaction Effects of Barely Genotypes and Inorganic Fertilizer Application With Regard to Grain Yield.....	41
4:Grain Yield Response Index.....	45

LIST OF APPENDICES

APPENDIX	PAGE
1: Mean Square Values Date of Emergency, Date of Heading and Date of Maturity.....	76
2: Mean Square Values of Plant Height, Number of Effective Tiller, Spike Length and Number of Grain Per Spike.....	76
3: Mean Square Values of Above Ground Total Biomass, Grain Yield And Straw Yield.....	77
4: Mean Square Values of 1000s Grain Weight and Harvest Index.....	77
5: Soil Ph Rating For 1: 2.5 Soils to Water Ratio Suspension.....	78
6: Mean Monthly and Annual Maximum Temperature at Hagerselam Hula Woreda (2010-2019).....	78
7: Mean Monthly and Annual Minimum Temperature at Hagerselam Hula Woreda (2010-2019).....	79
8: Monthly and Yearly Total Rainfall (Mm) at Hagerselam Hula Woreda (2010-2019).....	79

LIST OF FIGURES IN THE APPENDIX

FIGURE	PAGE
1: Land Preparation.....	80
2: Day of Sowing.....	80
3: Day of Weeding.....	81
4: Day of Urea Application.....	81
5: Field Supervision.....	82
6: Data Collection.....	83
7: Day of Harvesting.....	83

LIST OF ACRONYMS AND ABBREVIATIONS

ANA	Amount of nutrient applied
ANOVA	Analysis of variance
ANUE	Agronomic nutrient use efficiency
ATA	Agriculture transformation agency
CEC	Cat-ion exchange capacity
CSA	Central Statistical Agency
CV	Coefficient of variation
DAP	Di Ammonium phosphate
DMY	dry matter yield
ER	Efficient and respond
EthioSIS	Ethiopian soil information system
ETB	Ethiopia birr
FDA	food and Drug Administration
GB	gross benefits
GYRI	Grain yield response index
LSD	List significant difference
MRR	marginal rate of return
NB	net benefits
NENR	Non efficient not respond
NER	Non efficient but respond
RCBD	Randomized complete block design
T	Tone
TVC	total variable costs
USDA	United States Department of Agriculture

Response of Barely (*Hordeum vulgare* L) Genotypes to Inorganic Fertilizers Types under Acidic Soil of Hagerselam, Southern Ethiopia

Hailu Hameso (B.Sc), Waleligh Worku ((Ph.D.) and Tewodros Ayalew (M.Sc)

School of Plant and Horticultural Sciences, Hawassa University, P.O. Box 05, Hawassa, Ethiopia

ABSTRACT

Barley is one of the most important cereal crops in the world. It is a staple food grain, especially for Ethiopian highlanders. However, the barley productivity is commonly influenced by different biotic and abiotic factors. Soil acidity is one of the main environmental factors affecting growth and crop yield. Field experiment was conducted on acidic soil of Hagereselam, southern Ethiopia in 2019 cropping season to evaluate the performance of barley genotypes in terms of yield and yield components under different inorganic fertilizer types. The experiment was laid out in Randomized Complete Block Design with factorial arrangement with three replication and consisted of four fertilizer types (control, NP, NPS and NPSB) and four barley genotypes (217176b, 240478, 234911b and 208855b) and one barley variety (HB- 1307) as a check. Both main and interaction effects influenced days to physiological maturity, plant height, number of effective tillers m^{-2} , above ground total biomass and grain yield. However, days to heading, spike length, number of grain per spike, 1000 grain weight, straw yield and harvest index were only affected by main effects. Barley Genotype 217176b with NPSB fertilizer exhibited the highest grain yield of (4.9 ton ha^{-1}). However, it did not significantly differ from the yield obtained from the same genotype under NP (4.72 ton ha^{-1}) and genotype 240478 with NPSB fertilizer application (4.58 ton ha^{-1}). The lowest yield was recorded from genotype 208855b with control fertilizer. Genotypes 217176b and 240478 were categorized as efficient and responsive to fertilization under the evaluation. The highest marginal rate of return (MRR %), 3745.35, recorded from the application of recommended rates of NPSB fertilizer for genotype 217176b. Greater net benefits with more than the minimum acceptance value of 100% of MRR were obtained for the same genotype with NP. Similarly economically acceptable performances were obtained for genotype 240478 either with NPSB or NP fertilization. Given the fact that grain yield performance between the two genotypes in combinations either with NPSB or NP is not statistically significant, either of the two genotypes with the NPSB or NP fertilizer can be recommended for barley production in acidic soils of Hagereselam and acidic soils of similar agro-ecologies in the highlands of Ethiopia. Further studies that are replicated at least over seasons are needed to investigate response of the two promising barley genotypes to application of inorganic fertilizers under acidic soil conditions in order to come up with a conclusive recommendation.

Keywords: Barley Genotypes, Inorganic Fertilizer, Grain Yield, Soil Acidity

1. INTRODUCTION

1.1. Background and Justification

Barley (*Hordeum vulgare* L.) is a grass of the family Poaceae, the subfamily Pooideae and the tribe triticeae (Volas *et al.*, 1998). Barley is thought to have originated in the Fertile Crescent area of the Near East from the wild progenitor *Hordeum spontaneum* ((Saisho and Purugganan, 2007). Barley is one of the most important cereal crop in the world, ranking fourth in production area next to wheat, maize and rice (USDA, 2017). Barley is a staple food grain, especially for Ethiopian highlanders. It can be grown in diverse agro ecologies being grown from 1800 to 3400m altitude in different seasons and production systems (Muluken, 2013). Barley ranks the fifth important crop after maize, teff, sorghum and wheat in the country (CSA, 2018). Barley can serve as a substitute for wheat when wheat prices are high. Recent researches have established several health benefits of barley, predominantly because of its β -glucans content; hypocholesterolemic, hypoglycemic, obesity controlling, prebiotic, and anticancerous effects (Mulatu and Grando, 2011). Its grain contains carbohydrate, starch, protein and small amount of fat (Martin *et al.*, 2006).

The national average yield of barley in Ethiopia is low (2.16 ton ha⁻¹) (CSA, 2018). There are several factors that are contributing to low productivity of barley in the country such as genetic, environmental and socioeconomic constraints (Mulatu and Grando, 2011). Barley is also among the major grain cereals dominantly cultivated in the central and southern highlands of Ethiopia where the soils are often acidic. Barley can be cultivated and gives better yields in the diverse

environmental conditions, except in extreme high rainfall areas, which limit the yields (Getaneh, 2007).

Declining soil fertility is one of the major challenges to barley production and productivity in Ethiopia (Amsal and Tanner, 2001). Depletion of soil nutrients especially N and P could be one of the major reasons for the observed decreases in grain yield of barley. Some of the emerging research findings are also indicating that K is indeed becoming a limiting nutrient in some Ethiopian soils (Abiye *et al.*, 2013). Significant increases in grain and straw yields of wheat have been reported in vertisols of central Ethiopia due to application of potassium in the form of potassium sulphate (Abiye *et al.*, 2004). Abegaze (2008) also reported significant increase in the yield of barley due to K fertilization of luvisol in Atsibi Wonberama district in Tigray.

Similarly, nutrients such as sulfur and boron are also, found to be limiting in many soils of Ethiopia (Atlas, 2016). They further reported that Zn and Cu deficiencies were, observed in 40 and 85 % of maize crop samples, respectively. Ethiopian soil information system (EthioSIS) project is currently engaged in assessing the soil fertility status to develop soil fertility map of Ethiopia soils. It also reported wide spread occurrence of several micronutrient deficiencies in addition to macronutrients such as N and P. Based on such recent results, production and uses of blended fertilizers containing three or more nutrients have already been started in Ethiopia regardless of the past fertilizer application history.

Soil acidity determines the availability of nutrients to the plants. Due to complex and numerous factors involving in nutrient/element deficiencies and toxicities, low activity of beneficial microorganisms and reduced plant root growth, soil acidity limits nutrient and water uptake (Fageria and Baligar, 2003). Therefore, soil acidity is the most important soil factors, which affect plant growth, and ultimately limit crop production and profitability. The problem is

common in all regions where precipitation is high enough to leach appreciable amounts of exchangeable bases from the soil surface (Achalu *et al.*, 2012). There are considerable evidence in literature that showed that soil pH < 5.5 affects the growth of crops due to high concentration of aluminum (Al) and manganese (Mn), and deficiency of phosphorus, nitrogen, sulfur and other nutrients (Abreha, 2013). According to Mesfin (2007), and soil inventory data of EthioSIS acidic soils tend to be deficient in N, P, S and may be B which result in sever yield loses and deteriorated nutritional quality of the crops .

Several conventional strategies for farmers have been proposed to ameliorate soil acidity and/or decrease Al-accumulation through liming, P fertilization, and the production of low Al-accumulating cultivars through genetic manipulation (Chan and Liao, 2016). However, continuous application of P fertilizer and lime in soil is not only expensive but also environmentally risky (Vance *et al.*, 2003). Therefore, low-cost, effective and environmentally friendly approaches are in high demand. In this regard, the application of adequate mineral nutrition and use of acid tolerant varieties would be a suitable strategy for minimizing soil acidity related yield reduction.

Many crop plants have a range of susceptibility to acidic soils, and overall their performance is highly influenced by Al toxicity (Gupta, 2013). According to Tang *et al.* (2000), there is variation among different crops in the sensitivity to acidity/Al³⁺. Therefore, more attention has been given to study plant–nutrient–soil interactions as well as to minimize Al toxicity in plants exposed to acid soil by nutritional amendments (Guo *et al.*, 2017). In acidic soils, most of agricultural crops show poor performance even with the application of lime (Yasufumi, 2013). Instead, the soils are characterized by low pH below 5.0 (acidity) and cation (aluminium and manganese) toxicity especially in medium altitude zones of Kenya (Obura *et al.*, 2010;).

This may be responsible for the constantly low barley yields despite the release of high yield potential varieties.

1.2. Statement of the Problem

The average yield of barley (2.2 ton ha⁻¹) is low compared with the world average yields of 3.1 ton ha⁻¹. The low yield is attributed to the poor agronomic practices and soil nutrient mining, soil acidity, low fertilizer use, soil erosion, weed infestation and occurrence of pests. Despite the increase in a fertilizer use in Ethiopia, the type and rate practiced by the small scale-farmer deviates from the research proved rate and type. High price of fertilizer, farmers' awareness level on the use of fertilizers and limited consideration of other packages such as the lack of improved varieties, and use of un recommended agronomic practice are also among the factors contributing for the low yield of barley in Ethiopia. Soil acidity problem is constraints to improve crop production and productivity in high rainfall regions of Ethiopia in general and in study area in particular.

Hagereselam, Sidama Zone, has severe yield reduction problems. One reason for reduction is soil acidity problem. Soil acidity may arise due to, leaching of basic ions since the area receives high annual rainfall and practices poor soil management practices. Acidic soils may not adequately respond to inorganic fertilizers and/or may require application of higher rates. This makes the optimal fertilizer use in the acidic soils expensive for smallholder farmers. Therefore, this experiment was done to examine the response of barley genotypes, to inorganic fertilizers types under acidic soil and to evaluate and validate fertilizer types for the acidic soil at the study area.

1.3. Objectives

1.3.1. General objective

The aim of this experiment is to examine the response of barley genotypes to inorganic fertilizer sources under acidic soil Hagerselam, Sidama Region, Southern Ethiopia.

1.3.2. Specific objectives

1. To investigate the effect of inorganic fertilizers on growth, yield and yield components of barley genotypes on acidic soil
2. To determine the best performing barley genotypes in response to inorganic fertilizer types under acidic soil
3. To analyze the economic feasibility of fertilizer application for barley production under acidic soil conditions.

1.4 Hypothesis

H₀= Response of barley to all treatments will be the same irrespective of the application of different inorganic fertilizers.

H_a= Barley varieties will respond differently to the treatment sets of blended and unblended fertilizers under acidic soil.

2. LITERATURE REVIEW

2.1. Distribution and Importance of Barley

The domestication of barley assumed to have taken place from two-rowed wild barley (*Hordeum vulgare* L.) subsp. *spontaneum* in the Near East (Molina-Cano *et al.*, 2005). However, the six-rowed barley originated repeatedly at different times and in different regions, through independent mutations of allele (two-rowed spike) (Yang *et al.*, 2008). Barley grains are used as human food, to feed farm animals and for malt production, which in turn is used to make beer, whisky or other processed food products. In Japan, barley grains are used for special preparations (Kays *et al.*, 2005).

In the western world barley is becoming less important as a human food, and it is mainly used to feed farm animals or for malt production. On the other hand, in the highlands of Tibet, Nepal and Ethiopia and in some areas of North Africa, China and Russia, barley is still an important human food (Kemelew and Alemayehu, 2011). Because of its low demand as a human food and its lower yield potential compared to other cereals like wheat and maize, the barley area in the major barley producing countries is decreasing. Barley is effective in lowering blood cholesterol in hypercholesterolemic people with a higher risk of cardiovascular diseases (Ripple *et al.*, 2009).

Whole grain barley and barley containing products have been allowed to claim that they reduce the risk of coronary heart diseases by the US Food and Drug Administration (FDA, 2007). The nutritional and clinical importance of barley foods and public consciousness regarding quality of daily diet, that is cereal diversification, may have a positive impact on the demand of barley as a human food in the future. β -glucans occur in the fiber of grasses (*Gramineae*) such as barley,

oats, rye and wheat, generally in amounts of about 7%, 5%, 2% and less than 1%, 5 respectively. The main use of β -glucans is in texturizing as fat substitutes. They are recognized as having important positive health benefits centered on their benefits in coronary heart disease, cholesterol lowering and reducing the glyceemic response (Burkus and Temelli, 2005).

2.2. Cultivation of Barley in Ethiopia

Ethiopia is a center of origin and diversity for many cultivated crops and their wild relatives. The altitudinal variation, temperature and rainfall differences coupled with edaphic factors create a wide range of ecological conditions in the country (Mulatu and Grando, 2011). Since a wide range of agro-climatic conditions characterizes Ethiopia, barley is one of the major cereals grown in wide agro-ecology of the country with its economic and social importance. The useful characteristics of Ethiopian barley include high tillering capacity and tolerance to marginal soil conditions, barley shoot fly, aphids, frost, vigorous seedling establishment and quick grain filling period (Hailu and Alemayehu, 1991).

Barley is one of the oldest cultivated crops and has been grown in the highland parts of Ethiopia and various sources agree that it has been in cultivation for at least the past 5000 years and it is cultivated in all regions of the country (Kemelew and Alemayehu, 2011; Girma, 2014). The first Ethiopians to have ever cultivated barley are believed to be the Agew people, in about 3000 BC (reviewed by Zemedu, 1996). The area coverage for barley production in Ethiopia over the past 25 years has fluctuated. It was around 0.8 million hectares in the late 1970s, and rose to more than 1 million hectare in the late 1980s. It then declined and remained between 0.8 and 0.9 million hectare until the beginning of the third millennium. The production of barley usually has been below 1767518 hectares per year (CSA, 2018/19). Barley is a major staple food crop in the

highlands of northern Ethiopia. The crop is used for preparing various types of traditional food and beverage consumption such as *Kita, Kolo, Beso, Enjera, Giat, Tihlo* and many others (Araya, 2011). Concerning drinks the study showed that as many as 6 alcoholic and non-alcoholic local beverages are brewed in the household from barley grains for daily consumption or for holidays and celebrations. The barley straw is used in the construction of traditional huts and grain stores either as thatching or as a mud plaster (Zemedu, 2000).

2.3. Effect of Inorganic Fertilizer on Growth, Yield and Yield Components of Barley under Acidic Soil Conditions.

2.3.1. Phosphorus Fertilizer under Acidic Soil Conditions.

Phosphorus is an essential macro-mineral that plays an important role in plant growth and development under normal and/or stress conditions (Tariq *et al.*, 2017). In acidic soils, inorganic phosphate (Pi) is fixed by Al/Fe, it becomes critical when the pH drops and the result is a severe limitation of Pi in acid soils (Chen *et al.*, 2016). Consequently, plants surviving in acid soils have to face both Al toxicity and P deficiency. Exogenous application of P alleviates Al toxicity in a number of plants such as sorghum (Tan *et al.*, 1990), barley (Zheng *et al.*, 2005), and wheat (Iqbal *et al.*, 2013) on acid soils. Tan and Keltjens (1990) found that plant biomass production was not influenced by a low concentration of Al ($0.4 \text{ mg}\cdot\text{L}^{-1}$), but plant growth and dry matter yield (DMY) were severely inhibited at a high Al concentration ($1.6 \text{ mg}\cdot\text{L}^{-1}$) in barley.

In this regard, the addition of P alleviates Al toxicity by increasing root respiration and nutrient uptake that lead to enhanced DMY. Iqbal (2013) observed that P content in wheat seedlings largely reduced by Al stress ($150 \text{ mg AlCl}_3 \text{ kg}^{-1}$ soil) while conversely pH level is found to be balanced and P level is increased after addition of exogenous P (160 mg P kg^{-1} soil) to soil. Chen *et al.* (2012) provided a threshold of P for alleviating Al toxicity based on tested plants, and

indicated that if the value of P/Al molar ratio exceeds five in the root cells, Al toxicity could be alleviated. Recently, P application is reported to enhance plant growth, height, root collar diameter, and chlorophyll content in barley (Razaq *et al.*, 2017). Studies have indicated that phosphorus enhanced root system, which provides greater root-soil contact and eventually higher uptake of phosphorus and other important and low mobility nutrients and absorption of higher concentration of mineral nutrients (Zafar *et al.*, 2003).

Phosphorus fertilizer on yield and yield components of barley indicated promising effect in various parts Ethiopia. Research conducted on barley at Ellala Vertisols of Northern Ethiopia depicted that yield and yield components of barley is increased with increasing P fertilizers and increment of grain yield from 7.4075t/ha at the control plot to 11.1960t/ha at the rate of 20t/ha P with 50kg/ha of Urea was observed (Fisseha ,2008). Besides study conducted on barley in northern Ethiopia, Tigray region in three sites characterized by different climatic conditions during the cropping season of 2009/10 indicated that Grain yield has varied significantly ($p < 0.001$) in response to phosphorus fertilization across different sites.

However, at one site yield showed declining trend as rate of P increase from 20 to 30kg/ha. The maximum yield (1706 kg ha^{-1}) was obtained at P rate 20 kg ha^{-1} (Dejen and Fetien, 2014). Similarly an experiment conducted on the effects of different phosphorus fertilizer levels on yield and yield components of barley at south eastern Oromia, Bore, in 2009. Cropping indicated that P application significantly influenced all the parameters of growth and development of barley and the highest total biomass of 8.91 kg ha^{-1} were obtained from the highest P level of 69 Kg ha^{-1} (Wakene *et al*, 2014).

2.3.2. Response of Barley to Nitrogen under Acidic Soil Conditions

Continuous application of inorganic fertilizer without soil test and amendment, in the end increase soil acidity. The use of N fertilizers in form of ammonia is a source of acidification (Fageria and Nascente, 2014; Guo *et al.*, 2010). When ammonium fertilizers are applied to the soil, acidity is produced, but the form of N removed by the crop is similar to that found in fertilizer. Hydrogen is added in the form of ammonia -based fertilizers (NH_4), urea-based and as proteins (amino acid) in organic fertilizers. Transformation of such sources of N fertilizers into nitrate (NO_3) releases hydrogen ions (H^+) to create soil acidity. In reality, N fertilizer increases soil acidity by increasing crop yields, thereby increasing the amount of basic elements being removed by crop harvest without incorporation. Hence, application of fertilizers containing NH_4 or even adding large quantities of organic matter to a soil can ultimately increase soil acidity and lower pH (Guo *et al.*, 2010).

Nitrogen is the key nutrient input for achieving higher yield of barley. Barley is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization (Alam *et al.*, 2007). Similarly, Sinebo *et al.* (2003) also reported that about 65% of grain yield variability in barley was attributed to nitrogen stress. The most important role of nitrogen in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances from which the living material or protoplasm of every cell is made. Nitrogen increased leaf area, tiller formation, leaf area index and leaf area duration and this increasing is led to much greater production of dry matter and grain yield (Franklin *et al.*, 2017). Among the plant nutrients, nitrogen plays a very important role in crop productivity (Oikeh *et al.*, 2007; Worku *et al.*, 2007).

Although judicious dose of nitrogen elevates the yield and quality of grain but excessive dose causes the economic loss as well as reduced yield and quality of barley grain. Barley farmers in Ethiopia have not fully adopted modern inputs like fertilizer and modern seeds that help boost production (CSA, 2014). The yield attributes and quality of food barley seed is therefore, dependent on appropriate dose of nitrogen. Sustaining soil fertility in intensive cropping systems for higher yields and better quality can be achieved through optimum levels of fertilizer application. Thus, information on fertility status of soils and crop response to different soil fertility management is very crucial to come up with profitable and sustainable crop production. Besides to this, optimum dose of nitrogen depends on the climate and soil of the location as well as variety used (Shahnaj *et al.*, 2014).

Nitrogen deficiency is common in acidic soil and barley results restricted root growth, poor tillering, thinner and smaller stems, premature ripening of grains (Mishra and Shivakumar, 2005). Moreno *et al.* (2003) Working with influence of N fertilizer on yield of malt barley reported that the main effect of the N was decisive on all the parameters measured and the treatment without N supply was the least productive. Agronomic traits and yield components also positively influenced by N application (Fallahi *et al.*, 2008).

Although nitrogen requirements of crop met through addition of nitrogen fertilizer, it is an expensive input and those reflect its low consumption in Ethiopia highlands (Murinen, 2007). Nitrogen plays vital role in all living tissue of the plant. No other elements have such an effect on promoting vigorous plant growth. Abundant of protein tends to increase the size of the leaves accordingly, to bring about an increase in carbohydrate synthesis (Murenine, 2007). An appropriate N-application has been recommended by various research workers and reported N application in barley increased spike length, grain weight and grain yield (Hussuien *et al.*, 2005).

2.3.4. Response of Barley to Sulfur

Until the 1970's, S was mainly regarded as a neglected element in soil science, though it has a pivotal role in the production of protein, vitamins, chlorophyll, and glucoside oil in plants (Scott *et al.*, 1985). Recently, S has received more attention due to its capacity to modify metal toxicity as well as having a vital role in plant growth and development (Guo *et al.*, 2017; Dixit *et al.*, 2016; Saifullah *et al.*, 2016). Several studies have provided evidence that S-containing components alleviate Al toxicity in wheat (Zhang *et al.*, 2010), barley (Dawood, 2012), oilseed rape (Qian *et al.*, 2014) and citrus trees (Guo *et al.*, 2017). Recently, S addition (0.5 mM S; MgSO₄ and/or 0.5 mM Na₂SO₄) was shown to alleviate Al toxicity by increasing minerals (P, Mg and Ca) and relative water contents and a decrease Al and H₂O₂ contents, and involving S-metabolism and antioxidant enzymes in citrus (Guo *et al.*, 2017). Additionally, several studies have reported that S increased mineral components that supported to alleviate several metal toxicities, along with Al toxicity in plants (Guo *et al.*, 2017; Dixit *et al.*, 2016), and better increased NO₃⁻ and NH₄⁺ levels in the soil compared to an NPK fertilizer treatment (Skwierawska *et al.*, 2008).

Sutaliya *et al.* (2003) reported that the highest plant height is obtained from the rate of 45 kg S ha⁻¹ in barley. The sulphur application improved the soil structure and it increased the usefulness of other plant nutrients. Dewal and Pareek (2004) stated that the plant height in barley increased as the doses increased and the highest plant height obtained from 40 kg S ha⁻¹ application in wheat. Chaudhary *et al.* (2003) reported that the highest plant height is obtained from 60 kg S ha⁻¹ application in wheat.

Sutaliya *et al.* (2003) reported that the highest spike length is obtained from 45 kg S ha⁻¹ application. Gupta *et al.* (2004) observed that the highest spike length is obtained from 45 kg S ha⁻¹ application in barley. Sutaliya *et al.* (2003) found that the highest number of seed per spike is obtained from 45 kg S ha⁻¹ application. Dewal and Pareek (2004) reported that the number of seed per spike increased as the sulfur doses increased and they found the highest number of seed per spike with 40 kg S ha⁻¹ application in wheat. Gupta *et al.* (2004) reported that the highest number of seed per spike is obtained from 45 kg S ha⁻¹ application.

2.3.5. Response of Barley to Boron

Boron is an essential micronutrient, which is reported to decrease the accumulation of toxic Al in several plants. Effect of boron application on harvest index is claimed (Tahir *et al.*, 2009). The most effect of boron application on harvest index is reported anthesis stage in barley, As a result of the general immobility of boron in plants that is characteristic of most species; plants require a constant supply of boron during all phases of plant growth. The increase in the Harvest index due to micronutrients is attributed to its influences in enhancing the photosynthesis process and translocation of photosynthetic products to economic parts as well as increase enzymatic activity and other biological activities (Bameri *et al.*, 2012). Tahir *et al.*, (2009) observed minimum grain yield in the control i.e. without boron application. In addition, they have an opinion that grain yield increased with boron treatment due to the reason that the application of Boron enhanced pollen tube germination and grain setting. These inferences are in accordance with the Moeinian *et al.*, (2011) that believe Boron application has a key role in plant metabolism, root growth increase and by better use of nitrogen and synthesis of more carbohydrates and proteins and efficient water use.

2.4. Effect of Soil Acidity on Nutrient Availability and Crop Yield.

The detrimental effect of soil acidity on plant growth and yield is mainly attributed to the deficiency of phosphorus, which is caused by adsorption of P to colloidal fractions and conversion to insoluble Al and/or Fe compounds and toxicity of aluminum, iron and manganese (Brady and Weil, 2016). Deficiencies of calcium, magnesium, potassium and molybdenum have also been reported to limit crop yield in acid soils (Sumner, 2000). The solubility and availability of important nutrients to plants is closely related to the pH of the soil (Marschner, 2011). Soil pH affects the availability of plant nutrients. Effects of high acidity in a soil are shortage of available Ca, P and Mo on the one hand, and excess of soluble Al, Mn and other metallic ions on the other (Agegnehu and Sommer, 2000a).

Acid soil limits the availability of crucial nutrients such as P, K, Ca and Mg, and affects the movement of soil organisms plants need to stay healthy. If a particular soil is too acidic for plants to grow healthy, it is necessary to raise the pH by applying alkaline substance. Soil acidity and associated low nutrient availability is one of the constraints to crop production on acid soils. If a pH of a soil is less than 5.5 phosphates can readily be rendered unavailable to plant roots as it is the most immobile of the major plant nutrients (Agegnehu and Sommer, 2000b), and yields of crops grown in such soils are very low. In soil pH between 5.5 and 7, P fixation is low and its availability to plants is higher. Toxicity and deficiency of Fe and Mn may be avoided if the soil reaction is held within a soil pH range of 5.5 to 7 because this pH range seems to promote the most ready availability of plant nutrients. The quantity of P in soil solution needed for optimum growth of crops lies in the range of 0.13 to 1.31 kg P ha⁻¹ as growing crops absorb about 0.44 kg P ha⁻¹ per day (Lawlor, 2004).

2.5. Soil Acidity Management

The management of acid soils should aim at improving the production potential by the addition of amendments to correct the acidity and manipulate the agricultural practices to obtain optimum crop yields. The soil's acid/alkali balance (measured by pH) of the soil is very important in maintaining optimum availability of soil nutrients and minimizing potential toxicities. For example, at a very low pH Al may become more soluble and can be taken up by roots - becoming toxic, P may become unavailable and Ca levels can be low. At high pH, Fe and other micronutrients (except Mo) are rendered unavailable since they are locked up as insoluble hydroxides and carbonates (Slattery and Hollier, 2002).

2.5.1. Using Acid Tolerant Crop Varieties

If soil pH is low, using tolerant species/varieties of crops and pasture can reduce the impact of soil acidity. This is not a permanent solution because the soil will continue to acidify without liming treatment. A number of management practices can reduce the rate of soil acidification. Management of nitrogen fertilizer application is the most important practice to reduce nitrate leaching in high rainfall areas.

Less acidifying options in crop rotations can also help, e.g. replace legume hay with a less acidifying crop or pasture (Bolland *et al.*, 2004). The number of plant species of economic importance are generally regarded as tolerant to acid soil conditions. Many of them have their center of origin in acid soil regions, suggesting that adaptation to soil constraints is part of the evolutionary process. Although the species as a whole does not tolerate, some varieties of certain species also possess acid soil tolerance. Quantitative assessments of plant tolerance to acid soil stresses include tolerance to high levels of Al or Mn, and to deficiencies of Ca, Mg, P,

etc. Species and genotypes within a species have been reported to have considerable variation in their tolerance to Al and Mn. The selection of varieties or species that perform well at high Al saturation levels and thus need only a fraction of the normal lime requirement is of great practical importance. In the highlands of Ethiopia, barley is mainly grown on Nitisols, where soil pH is low. This means that barley has been already adapted to acid soil conditions. Among five released barley varieties evaluated under limed and unlimed condition on acidic soils at Endibir, two varieties (HB-42 and Dimtu) performed well under limed condition (Kochian *et al.*, 2004).

2.6. Genotypic Differences in Response to Fertilizer Application under Acidic Soil

Acid tolerance has been evaluated by different methods around the world (Hossain *et al.*, 2005). Some barley varieties with high Al tolerance were identified, although most of them were sensitive (Maxim and Duta, 1996). In general, 6-row cultivars are more tolerant than 2-row and 4-row types; husked ones are more tolerant than naked and winter cultivars are more tolerant than spring ones (Xu *et al.*, 1991). All eight tolerant barley cultivars ranked by Minella and Sorrells (1992) are six-row cultivars. Two row barleys having Al tolerance have also been reported (Raman *et al.*, 2002). Acid tolerance in barley has been assessed by root staining using hematoxylin (Tang *et al.*, 2000) and eriochrome cyanine (Wang *et al.*, 2006). These qualitative variations have been assessed as stained, unstained and partially stained to represent Al-sensitive, tolerant and intermediate genotypes respectively. Al tolerance based on relative root re growth in barley has also been assessed as a quantitative trait (Raman *et al.*, 2005).

2.7. Mechanisms of Barley Tolerate to Acidic Soil

Around 30% of arable land in the world is acidic (von uexkull and Mutert, 1995). Plant species vary widely in their ability to grow and yield on acid soils (Foy, 1983). Some species and even

cultivars within certain species have evolved mechanisms to adapt to acid soils. Barley is considered one of the most soil acidity sensitive cereal crops, and rice the most resistant. Two main mechanisms of resistance have been proposed as exclusion mechanism and resistance mechanism.

The exclusion mechanism prevents Al from entering cells and minimizes Al toxicity, while the resistance mechanism allows plants to take up Al and accumulate Al within their cells (Kochian *et al.*, 2004). In addition, aluminum resistance between resistant wheat and barley was significantly different. For example, in nutrient solutions, Al resistant wheat ‘ET8’ can grow well with over 90% of relative root length at 20 μMAlCl , whilst the resistant barley ‘Dayton’ can only achieve this level of root growth in 2 μMAlCl (Zhou *et al.*, 2013).

In Barley, Lima Echart *et al.* (2002) indicated that the F2 generation analyzed with haematoxylin staining followed the Mendel’s segregation ratio of 3:1 for Al toxicity tolerant to susceptible plants; revealing the fact that the trait is controlled by single dominant gene. It is generally agreed that Al tolerance in barley is conditioned by the *Alp* locus which is located on the long arm of chromosome 4H. This locus is associated with Al-induced efflux of citrate from root apices of tolerant barley varieties (Wang *et al.*, 2006). A gene encoding a multidrug and toxic compound extrusion protein is proposed as a candidate gene for Al-tolerance in Barley (Wang *et al.*, 2007). In addition, quantitative trait loci that could explain 50% of the phenotypic variation are also associated with the same chromosomal location (JianFeng *et al.*, 2004). Similarly, Raman *et al.* (2005b) identified quantitative trait loci for root elongation under aluminum stress on 3H, 4H, 5H and 6H chromosomal locations.

3. MATERIALS AND METHODS

3.1. Description of Study Site

This study was conducted at Hagerselam, southern Ethiopia during the main cropping seasons of 2019. Hagerselam is located at $38^{\circ} 27'44''$ E longitude and $06^{\circ} 26'59''$, N latitude. The altitude of the experimental site is 2648 m a s l. The climate of the site is sub-humid type with bi-modal rainfall pattern. The main rainy season is extends from June to September and mean annual precipitation of the site range from 1000-to- 1300 mm. According to Ethiopian agro-ecological classification the area is grouped under highland with intensive rainfall. Among the cereal crops, the major crops grown in the area include wheat (*Triticum aestivum* L.) and barley. According to FAO, (1998) soil classification system the dominant soil type of the study site is Nitiosls, with textural class of clay loam.

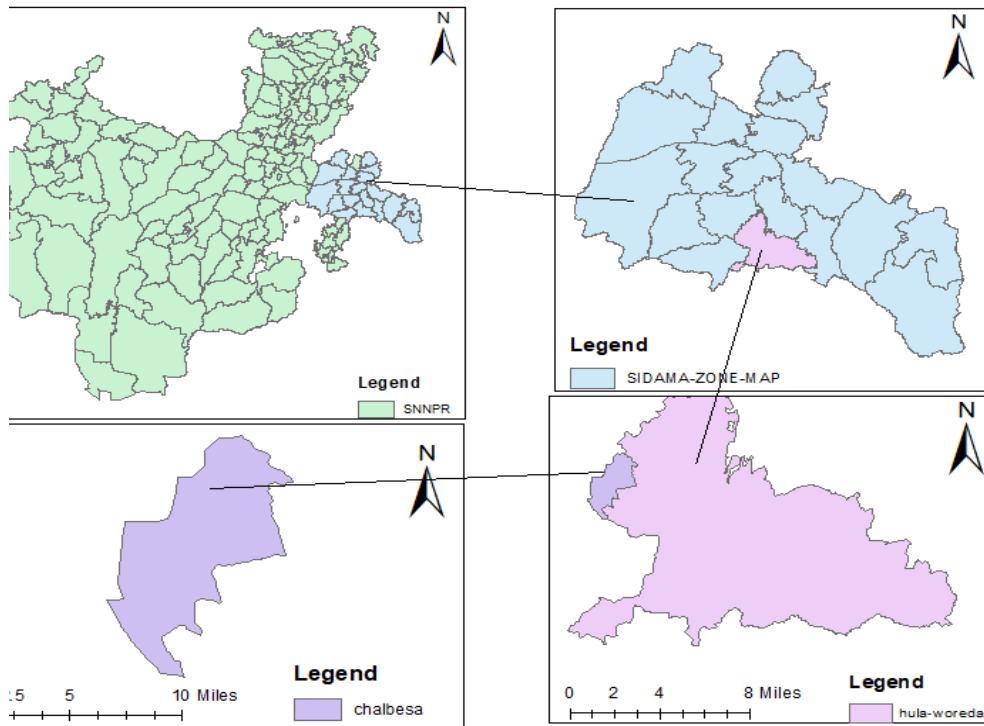


Figure 1: Geographical location map of the study area.

3.2. Treatments, Experimental Design and Procedures

Factorial experiment consisting of four fertilizer types (control (N), NP, NPS, NPSB), and four barley genotypes from Ethiopian Biodiversity institute (217176b, 240478 and 234911b) collected from Keficho Shekicho Zone, Decha worda, Chena worda and Masha Anderacha worda respectively. Genotype (208855b) collected from Hagereselam, Sidama Region and one variety (HB-1307) was developed by Holetta Agricultural Research Center and released in 2006 for mid and high altitude areas were used as experimental material. A Total of 20 treatments combination (4X5) was laid out in RCBD with three replications (Table 2.). The spacing between plots and block was 0.5 m and 1m, respectively. The plot size was 1.6 x 1.5 m (2.4 m²) accommodating eight rows of barley seed was sown at a spacing of 20 cm between rows. Two outer most rows and 0.15 m row length at both ends were considered as borders. The sample was taken from six middle rows. The recommended rates of NPS at 100 kg ha⁻¹ NPSB at 100 kg ha⁻¹, and NP at 100 kg ha⁻¹ fertilizer were applied as basal dressing at the time of sowing barley.

The experimental field was prepared by using local plough (Maresha) according to farmers' conventional farming practices. The urea was applied 45 days after planting of the experiment at the rate of N fertilizer in the form of urea was applied to all treatments with low proportion of N in order to meet the recommended dose of N fertilizer. Other Agronomic managements such as weeding, cultivation and pest control were done as per the recommendation for barley production in Ethiopia.

Table1: Combinations of the Treatments under the Study.

Barely genotypes	Types of fertilizers	Treatment combination
217176b	Control (N)	217176b x control
	NPS	217176b x NPS
	NPSB	217176b x NPSB
	NP	217176b x NP
208855b	Control	208855b x control
	NPS	208855b x NPS
	NPSB	208855b x NPSB
	NP	208855b x NP
234911b	Control	234911b x control
	NPS	234911b x NPS
	NPSB	234911b x NPSB
	NP	234911b x NP
240478	Control	240478 x control
	NPS	240478 x NPS
	NPSB	240478 x NPSB
	NP	240478 x NP
HB – 1307 (check)	Control	HB - 1307 x control
	NPS	HB - 1307 x NPS
	NPSB	HB - 1307 x NPSB
	NP	HB - 1307 x NP

Table 2: Types and the nutrient contents of the fertilizers used for the experiment

Types of fertilizers	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	S (kg.ha ⁻¹)	B (kg ha ⁻¹)
Control	46	0	0	0
NP	64	46	-	-
NPS	65	38	7	-
NPSB	64.9	37.7	6.95	0.1

3.3. Pre-Sowing and Post Harvest Soil Analysis

Soil analyses for specific parameters relevant to the current study were carried out at the soil laboratory of Hawassa soil testing laboratory .Surface soil samples (0-20 cm), 25 in number, were collected randomly by Auger sampler in a zigzag pattern before sowing the crop from the entire experimental field and composited into one sample. Soil samples after harvesting were

taken with treatments base and from this mixture, a sample weighing 1.0 kg was taken. Air-dried soil sample was ground with a wooden pestle and mortar under shading. Before analysis, the sample was sieved through a 2-mm sieve mesh. Soil pH was determined by glass electrode pH meter method (Piper, 1967) in 1:2.5 soil water suspensions as described by Jackson, (1973). Organic carbon was determined by Walkley and Black's rapid titration method (1934) as described by Piper (1966). The total nitrogen in soil was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1965). Available phosphorus was estimated by the ascorbic acid method as described by Olsen, (1954). Available boron was determined using hot water method (Havlin *et al.*, 1999).

3.4. Data Collection and Analysis

Days to emergence was determined by counting the number of days from sowing to the time when 50% of the plants started to emerge from the tip of panicles through visual observation. Day to heading was determined as the number of days from sowing to the time when the plants reached heading based on visual observation. Days to maturity were determined as the number of days from sowing to the time when the plants reached full physiological maturity. Plant height was measured at physiological maturity from the ground level to the tip of panicle from five randomly selected plants in each plot. Spike length was the length of the spike from the node where the first spike branches emerge to the tip of the spike, and was determined from an average of five selected plants per plot. The numbers of tillers were determined by counting the tillers from an area of 1 m x 1 m plants by throwing a quadrant into the middle portion of each plot. Five ears were taken randomly from each plot and number grain/ spike, was measured at physiological maturity of the crop prior to harvest.

The weight of 1000 seeds was determined by carefully counting the grains and weighing them using a sensitive balance. Grain yield was measured after harvesting the crop from the net plot area of 1.8 m² containing from six rows to avoid border effects. Biomass yield was measured by weighing the sun dried total above ground plant biomass (straw + grain) of the net plot. Straw yield was measured by subtracting the grain yield from the total above ground biomass yield after threshing. Harvest index was calculated by dividing grain yield by the total above ground air dry biomass yield. Grain yield response index (GYRI) was calculated for each genotype according to Fageria and barbosa-filho (1981) by selecting fertilizer that caused the highest response, using the following equation:

$$\text{GYRI} = \frac{\text{Grain Yield Under NPSB Fertilizer Applied} - \text{Grain Yield Under Zero Fertilizer}}{\text{high NPSB level} - \text{low NPSB level}} \times \text{kg grains kg NPSB}^{-1}$$

3.5 Economic Analysis of Treatment Effects

Economic analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The net benefit was calculated as the difference between the gross field benefit (ETB ha⁻¹) and the total variable costs (ETB ha⁻¹). The average price of each type of inorganic fertilizers was determined in Birr per 100 kg. Labor cost for fertilizer application was estimated as day required applying fertilizer. Each person-day labour cost was determined in Birr. Following the CIMMYT partial budget analysis method, total variable costs (TVC), gross benefits (GB) and net benefits (NB) was calculated. Then treatments were arranged in an increasing TVC order and dominance analysis was performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower net benefit. A treatment which is non-dominated and having a MRR of greater or equal to 100% and the highest net benefit is said economically profitable (CIMMYT, 1988).

3.6. Statistical Analyses

Data on yield components, grain and straw yields were subjected to ANOVA using SAS software version 9.0 (SAS, 2004). For parameters those ANOVA tested significant with respect to treatment effects, further means separation was done using least significant difference method (LSD) at 0.05 probability level.

4. RESULTS AND DISCUSSIONS

4.1. Physico-Chemical Properties of the Study Soil

4.1.1. Soil Physico-Chemical Properties of the Experimental Site before Sowing

According to the laboratory analysis, the soil texture of the experimental area was dominated by clay. The soil texture (proportion of sand, silt and clay in the soil) of experimental site was 31% sand, 32% silt and 47 % clay. Thus, the texture of the soil was clay loam (table 3). The textural properties of the soil influence water holding capacity, plant water , aeration, root penetration and soil fertility.

The pH of the soil was 4.48 (Table 3) which was strongly acidic (Tekalign, 1991). Brady and Weil (2002) have established a pH range of 5.5 to 7.0 to be associated with satisfactory availability of plant nutrients. Therefore, the soils of experimental site need reclamation to raise the pH and make them favorable for plant growth. This low value of soil pH could be due to loss of base forming cations down the soil profiles through leaching and drain to streams in runoff (Nigussie and Kissi, 2012).

The OC concentration of the study site was 2.38% (Table3). According to Landon (2014) the categories for the OC content of soils are: Very low (< 2%), low (2- 4), medium (4 - 10), high (> 10). Thus, the OC content of the soil is rated as low. This could be due to intensive agricultural activities that led to depletion of soil organic matter content. In addition, removal of crop residues for livestock feed and constriction of house aggravated depletion of SOC. Total nitrogen value of the experimental soil was (0.14). According to Ethio SIS (2014) TN content <0.1, 0.1-0.15, 0.15-0.3, 0.3-0.5, and >0.5 is rated as very low, low, medium, high and very

high, respectively. The result indicated N is a limiting factor for crop growth. The optimum N level needed for crop production under most soils of Ethiopia is reported to be <0.2 % according to EthioSIS (2013). Due to this nitrogen amendment is important at study area. Available P content of the experimental site was 4.21 mg kg⁻¹ (Table 3). According to Bray (1995) when the range of phosphorus in Bray method is <7, 8-19, 20-39, 40-58 and >59, it is rated as very low, low, medium, high and very high, respectively. EthioSIS (2014) suggest optimum P content for most Ethiopian soil as 15 mg kg⁻¹. Based on this, the available phosphorous of the study area is very low and needs phosphorous fertilizer. This low phosphorous content is due to intensive mining of the farm fields and fixation by heavy metals (Al, Fe and Mn). Masresha (2014) also reported low amount of P content on soils which are cultivated repeatedly due to P fixation and P mining. Similarly, Habtamu, *et al.* (2015) reported that under acidic soil low content of P was due to fixation problem.

The CEC of the site was 19.78 cmol kg⁻¹ (Table 3). Landon, *et al.* (1991) reported that soils having CEC of >40, 25-40, 15-25, 5-15, < 5 cmol kg⁻¹ are categorized as very high, high, medium, low and very low, respectively. According to the result obtained from soil laboratory, the value of CEC was in medium range. Available boron in the study area was 0.47 mg kg⁻¹ (Table 3). According to Ethio SIS (2014) critical B value for most Ethiopian soils is 0.8 mg kg⁻¹. This shows that soils of the study area are deficit in B suggesting application for fertilizer which contains B. Intensive cultivation and crop residual removal in the area might be responsible for low B content of the soil.

Table 3: Physic- chemical Characteristics of the Experimental soil before sowing

Soil properties	Value
Sand	31%
Silt	32%
Clay	37%
Texture class	Clay loam
PH	4.48
OC	2.38
TN%	0.14
Available P(mg kg ⁻¹)	3.56
B (mg kg ⁻¹)	0.47
CEC (Cmol (+) kg ⁻¹)	19.78
Exchangeable acidity (cmolc kg ⁻¹)	0.92

4.1.2. Soil Physico-Chemical Properties of the Experimental Site after Harvesting

The result of the data depicted that the greater pH (4.75, 4.73, and 4.71) were recorded from NPSB followed by NPS (4.54, 4.53, and 4.51) and the minimum pH was 4.44, which was recorded from control and NP (Table 4). This may be due to the fact that NPSB fertilizer is soluble and easy for uptake by the crop. Crops under acidic soil take nitrogen in the form of NH₄ rather than No₃⁻ because microorganism activity is slow in acidic soil to change NH₄ to No₃⁻. Due to this there was no H⁺ releasing to the soil. But due to application of NP there was H⁺ releasing to the soil and also NP is not easily soluble and the crop cannot take nutrients easily and there was H⁺ releasing to the soil from NH₄. The use of N fertilizers in the form of ammonia is a source of acidification (Fageria and Nascente, 2014).

The result of the data depicted that the maximum residual available nitrogen (0.153%) was recorded from NP and the minimum available nitrogen (0.14 and 0.142 %) was recorded from control and NPSB. This is because NPSB is soluble and the available N from NPSB is absorbed by plant and leached into sub surface of the soil due to high rainfall. Gong *et al.* (2009) reported that balanced application of N and P fertilizers for 18 years showed higher N contents of the light and heavy fractions than in unbalanced N and P fertilizer treatments.

The result of the data indicated that the maximum available phosphorus (4.99, 4.97 and 4.96) mg kg⁻¹ were obtained from recommended NP and minimum available phosphorus was (3.22) mg kg⁻¹ recorded from control fertilizer due to NP is slowly soluble and P is not mobile in soil and not susceptible to leaching. Maximum organic carbon (2.57%) was reported from NP while minimum organic carbon (1.25%) was recorded from control. Application of NP fertilizers with optimum level resulted in increased residual inorganic N, which can enhance mineralization and increase of SOC. Ladha *et al.* (2011) observed overall averages of 8% higher SOC with fertilizer N than with zero-N. Significant increase in the SOC was observed in the optimum fertilizer applications of N and P treatments as compared to in the no-fertilizer treatment Tian *et al.* (2015).

Table 4: Effect of different types of Inorganic Fertilizers and Barley Genotypes Combinations on Soil Chemical Properties under Acidic Soil, After Harvesting

Genotypes	Fertilizers	PH pH(1:2.5) w/v	CEC(Cmol (+) kg-1)	N%	P(mg kg ⁻¹)	B(mg kg-1)	EA cmolc kg ⁻¹	OC %
217176	control	4.45	22.98	0.143	3.25	0.42	0.93	1.27
	NPS	4.51	23.11	0.149	4.89	0.43	0.59	2.46
	NPSB	4.73	24.42	0.146	4.76	0.52	0.53	2.23
	NP	4.46	23.18	0.151	4.97	0.45	0.65	2.51
28855b	control	4.43	22.96	0.139	3.22	0.41	0.96	1.29
	NPS	4.51	23.13	0.148	4.91	0.44	0.58	2.44
	NPSB	4.71	24.41	0.141	4.79	0.57	0.52	2.24
	NP	4.45	23.19	0.153	4.51	0.43	0.62	2.53
234911b	control	4.42	22.98	0.14	3.23	0.44	0.96	1.25
	NPS	4.53	23.14	0.147	4.87	0.42	0.61	2.44
	NPSB	4.75	24.45	0.142	4.79	0.55	0.54	2.25
	NP	4.45	23.2	0.149	4.99	0.42	0.64	2.54
240478	control	4.41	22.97	0.142	3.24	0.40	0.96	1.25
	NPS	4.53	23.12	0.147	4.92	0.44	0.57	2.49
	NPSB	4.73	24.41	0.144	4.77	0.59	0.51	2.25
	NP	4.44	23.17	0.15	4.96	0.46	0.63	2.54
HB-1307	control	4.44	22.96	0.141	3.26	0.43	0.96	1.29
	NPS	4.54	23.12	0.145	4.87	0.44	0.58	2.43
	NPSB	4.75	24.45	0.143	4.75	0.62	0.53	2.22
	NP	4.47	23.19	0.149	4.51	0.45	0.66	2.57

4.2. Crop Phenology and Plant Height

4.2.1. Days to Emergence and Heading

Days to emergence was significantly ($P \leq 0.001$) affected by genotypes but not by the types of inorganic fertilizers and their interaction with the genotypes. The mean numbers of days required to emergence were between 6 to 9 days for the tested genotypes (Table 5). The shortest days to emergence was recorded from barley genotype 240478, while the longest day to emergence was recorded from HB-1307. Significant variation was not observed on days to emergence by fertilizer application. This is due to the fact that, during germination the seedling mostly depends on stored food than on external nutrient. This is in conformity with the findings of

Shrivastava *et al.* (1992) who reported that plants depend mostly on stored food than on external nutrients for germination and early establishment.

Days to heading was significantly ($P \leq 0.001$) affected by the main effects of genotypes and fertilizers, but the interaction effect was not significant for days to heading (Table 5). The shortest day to heading 56 days was recorded from genotype 240478 while the longest day to heading 93 days was recorded from HB-1307. This could be due to variation in genetic makeup. Similarly, Daniel *et al.* (2013) reported that barley genotypes differ in days to heading. This result is also in line with the findings of Aynewa *et al.* (2013) on their work on participatory evaluation of barley genotypes for yield and other agronomic traits that showed significant difference among ten genotypes on both days to heading and maturity.

All fertilized plots had relatively shorter days for heading compared to the control with no significant difference among the fertilizer types (Table 5). The lack of significant difference among the fertilizer types on days to heading might be due to the constant N and P level as N and P are the major nutrient affecting such phenological parameters. This result is in line with Debritu (2013) who suggested that the supply of N and P contribute to vigorous, rapid growth and early heading of wheat crop.

Table 5: Main Effects of Inorganic Fertilizers and Barley Genotypes on Days to Emergence and Heading under Acidic Soil, during 2019 cropping season

Treatments	Day to emergence	Day to heading
Fertilizers types		
control	8	78a
NP	8	73b
NPS	8	72b
NPSB	8	71b
Fertilizer	NS	***
LSD	-	1.15
Genotypes		
217176b	7c	65d
240478	6d	56e
234911b	8b	72c
208855b	9a	81b
HB- 1307	9a	93a
Genotype	***	***
Fertilizer x genotypes	NS	NS
CV	2.89	2.13
LSD	0.19	1.29

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

4.2.2. Effects on Days to Physiological Maturity

Days to physiological maturity was significantly ($P \leq 0.001$) affected by the main effects of genotypes, the types of inorganic fertilizers and by their interaction (Table 6). The number of days required to physiological maturity varied between 77 and 140 days among genotypes. Longest mean value of day to maturity was recorded from the check HB-1307 with control fertilizer. The shortest day to maturity was recorded for barley genotype 240478 at NPSB

followed by genotype 240478 with NP and NPS application. The significant difference among the genotypes for these phenological traits may be attributed to their genetic difference which reflects their differential response to environmental conditions. Similarly, Wosene *et al.* (2015) reported that genotypes could differ in days to physiological maturity.

Table 6: Interaction Effect of Barley Genotypes with the Types of Inorganic Fertilizers on Physiological Maturity.

Genotypes	Days to physiological maturity			
	Types of fertilizer			
	Control	NP	NPS	NPSB
HB-1307	140a	120 b	120b	120b
208855b	106c	100d	102d	99d
234911b	92e	85fg	86 f	84f
217176b	90e	83fg	85fg	82gh
240478	85fg	79hi	79hi	77i
Interaction		***		
CV		2.306		
LSD		3.73		

Means followed by the same letters across rows and columns are not significantly different at ($p \leq 0.05$).

4.2.3. Plant Height

Analysis of variance showed that plant height was significantly ($P \leq 0.001$) affected by the main effects of barley genotypes, main effect of inorganic fertilizers and their interaction effect (Table

7). In plant height, mean value of genotypes ranged from 63 cm to 110 cm. Similarly longer plant heights of 110.287, 109 and 105.95 cm were recorded from genotype 217176b with the applications of NPSB, NP and NPS respectively. There was no significant difference on the plant heights recorded from genotype 217176b with fertilizers types and from genotype 240478 with NPSB and NP. The shorter plant heights were recorded from all genotypes with control fertilizer. The variation in the response may be due to differences in genetic makeup among the genotypes tested. Shahzad *et al.* (2007) reported that height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors. Phosphorus application was reported to enhance plant growth, height, root collar diameter, and chlorophyll content in barley (Razaq *et al.*, 2017). This result is in agreement with Minale *et al.* (2011) and Wakene *et al.* (2014) who reported that plant height of barely was increase with application of N fertilizer. In line with this result, Debnath *et al.* (2011) reported that boron application had significant effect on the plant height of wheat showing a range of heights from 89.7-97.3 cm. Boron is an essential micronutrient, which is reported to decrease the accumulation of toxic Al in several plants and enhance the nutrient uptake (Tahir *et al.*, 2009).

4.3. Yield Components Affected by Barley Genotypes and Inorganic Fertilizer Types

4.3.1. Number of Effective Tillers

The analysis of data revealed significant difference ($P \leq 0.001$) due to interaction effects of genotypes with types of inorganic fertilizers on effective tiller number. Greater mean number of effective tillers m^{-2} was recorded from genotype 217176b treated with recommended NPSB, and this had no significant difference to that produced by 217176b genotype with NP and NPS and also to that from genotype 240478 with NPSB. Whereas, the lower mean number of effective tillers were recorded from genotype 208855b treated with all types of fertilizers and also from

HB-1307 with control fertilizer (Table 7). Generally, genotype 217176b tended to respond better to NSPB, NP, and NPS fertilization and also genotype 240478 for NPSB. This might be attributed to different capacity of genotypes in tillering and also due to environmental factors. This is in agreement with that of Suleiman *et al.* (2014), who reported significant difference among varieties for tillering. In line with this result, Frehiwot (2014) reported that N and P fertilizer had potential role in number of total and effective tiller production per plant.

This variation could also happened due to the synergetic effects of boron nutrients increasing nitrogen nutrient use efficiency on genotype 240478. Boron is an essential micronutrient, which is reported to decrease the accumulation of toxic Al in several plants and increase nitrogen nutrient use efficiency (Tahir *et al.*, 2009). Similarly, Berhan (2012) reported that application of blended fertilizer brought significant difference in this parameter. The yield of crops is dependent upon the combined effect of many factors. Among these factors, the number of tillers per plant has a vital position, controlling yield of barley. The more the number of tillers, the better will be the stand of crop, which ultimately increase the yield (Jamawal and Bhagat, 2004).

Table 7: Interaction Effect of Barley Genotypes and Types of Inorganic Fertilizers on Plant Height and Number of Effective Tillers.

Treatments		Plant height (cm)	Number of effective tiller (m ⁻²)
217176b	NPSB	110.28a	69.33a
	NP	109.03a	65.33ab
240478	NPSB	108.86a	65.0ab
	NP	102.7abc	59.3bcd
217176b	NPS	105.95ab	62.3abc
240478	NPS	98.2bc	58.6bcd
234911b	NPSB	94.98cd	55.3cd
	NP	87.51de	54.0d
	NPS	85.59ef	53.3d
HB-1307	NPSB	79.497fg	36.33ef
	NP	76.25gh	36.0ef
	NPS	75.98gh	36.0ef
208855b	NPSB	79.843efg	27.3gh
	NP	75.807gh	24.6gh
	NPS	74.673gh	24.66gh
217176b	control	71.24gh	35.667ef
240478	control	73.81gh	38.66e
234911b	control	66.77hi	30.33ef
HB-1307	control	62.89i	28.3gh
208855b	control	68.61hi	22.66h
Interaction		***	***
CV		5.69	9.55
LSD		8.16	7.01

Means followed by the same letters across column are not significantly different at ($p \leq 0.05$).

4.3.2. Spike Length

Spike length was significantly ($p < 0.001$) influenced by the main effects of types of inorganic fertilizers and genotypes, but not, by the interaction effect (Table 8). Genotype 217176b and 240478 produced longer spike length with no significant difference between the two genotypes and lower spike lengths were obtained from variety HB- 1307 and genotype 208855b.

Longer spike lengths were recorded from the plots treated with recommended NPSB and NP application without significant difference between each other. These were improvements by

66.591 and 63.36% from NPSB and NP as compared to the shortest spike length (6.72 cm) obtained from zero fertilizer, respectively. The result indicated that macronutrient (N, P and S) and micro nutrient (boron) might have enhanced spike length of plants. On other hand, nitrogen and phosphorus had played a major role for cell division and elongation. The result is in agreement with the results of Debnath *et al.* (2011), Fayera *et al.* (2014), and Nasser (2009) who reported that the spike length of wheat significantly increased as a result of applying B blended fertilizer with macro nutrients. Bekalu and Mamo (2011) also reported that, optimum application of balanced nutrients has significant effect on spike length growth.

4.3.3 Number of Grain per Spike

The analysis of variance showed that grain number per spike of barley was significantly influenced ($P \leq 0.001$) due to main effects of genotypes and different types of inorganic fertilizers but not interaction effect (Table 8). The highest mean numbers of grain per spike (46.23) was recorded from genotype 217176b while the lowest mean (20.31), was obtained from genotype 208855b. This might be due to the presence of genetic difference among the tested genotypes. Adane (2015) reported presence of genotypic differences of barley in spikelet per spike, which in turn resulted in higher numbers of grains per spike. Reports have shown the variation in number of grain per spike as a function of differences in barely genotypes (Ryan *et al.*, 2009). This result is also in agreement with that of Guluma *et al.* (2010) who reported significant difference among three varieties of wheat on number of kernels per spike and 1000 kernel weight.

The highest mean numbers of grain per spike (41.9) was recorded from NPSB while the lowest mean (26.12), was obtained from the zero fertilizer (Table 8). This could be due to enhanced uptake of nitrogen, phosphorus and sulfur resulting from blending the nutrients with Boron.

Moeinian *et al.*, (2011) suggested that boron application has a key role in plant metabolism and root growth as contributes to better use of macro and micronutrients and synthesis of more carbohydrates and proteins. In agreement with this result Debnath *et al.* (2011) reported that Boron application enhanced a significant improvement in the number of seeds per spike of wheat.

4.3.4. Thousand Grain Weight

Analysis of variance revealed that thousand-grain weight (TGW) was significantly different among the tested genotypes ($P \leq 0.001$), due to main effect of genotypes and types of inorganic fertilizers but no interaction effect. Genotypes 217176b produced the highest thousand-seed weight (38.03g) (Tables 8). On the contrary, the lowest value of thousand-grain weight (27.74g) was recorded from 208855b genotype. This may be due to the suitable genetic behavior of 217176b that led to an increased photosynthesis process and accumulations of carbohydrate in seed to produce heavy kernels and consequently increased seed weight per spike. Similarly, Rashid and Khan (2008) and Yetsedaw *et al.* (2013) reported presence of variation in thousand grain weight among barely genotypes.

Greater thousand-grain weights were obtained from the recommended rates of NPSB and NP without statistically significant difference between the two treatments. The lowest grain weight (20.96 g) was obtained from the control. The absence of significant difference on thousand grain weights between NPSB and NP might be due to the constant application of major nutrients (N and P) in both fertilizers, which play the major role in growth and development of a crop.

Table 8: Main Effect of Barley Genotypes and Types of Inorganic Fertilizers on Spike Length (SL), Number of Grain per Spike (NGS) and Thousand Grain Weight (TGW) under acidic soil

	SL	NGS	TGW
Fertilizers			
NPSB	9.9093a	41.901a	37.5120a
NP	9.4320ab	39.351b	36.2160ab
NPS	8.8880b	38.416b	35.5847b
control	6.7213c	26.120c	20.9560c
Fertilizer	***	***	***
LSD	0.72	2.33	1.47
Genotypes			
217176b	10.9858a	46.231a	38.0333a
240478	10.3292a	43.502b	35.9700b
234911b	8.2367b	39.474c	31.1600c
HB- 1307	6.8425c	32.723d	29.9300c
208855b	7.294c	20.306e	27.7425d
Genotype	***	***	***
Fertilizer X genotypes	NS	NS	NS
CV	11.26	8.65	6.11
LSD	0.81	2.6	1.64

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

4.4 Yield Traits Affected by Barley Genotypes and Inorganic Fertilizer Types

4.4.1 Above Ground Biomass

The analysis of variance showed that, above ground biomass yield was significantly ($P \leq 0.001$) different among genotypes, the main effect of inorganic fertilizer types and the interaction effect of fertilizer and genotypes (Figure 2). The significantly higher biomass yields of 9.96 and 9.54

ton ha⁻¹ were recorded from genotypes 217176b and 240478, respectively while genotype 208855b had the lowest biomass yield 5.62 ton ha⁻¹ (Figure 2).

The highest biomass yield (9.64 ton ha⁻¹) was obtained with application of NPSB and the lowest (4.60 ton ha⁻¹) from the control (with zero fertilizer). Compared to control fertilizers, the above ground biomass was increased by 47.71%, due to application of blended fertilizer NPSB.

The analysis of variance showed also that biomass yield of barley was significantly influenced ($P \leq 0.05$) due to interaction effects of genotypes and the different types of inorganic fertilizers (Figure 2). The significantly higher biomass yields were obtained from genotypes 217176b and 240478 with application of NPSB and NP fertilizers without statistical difference among them. Lower biomass yields were recorded for all genotypes under the zero fertilizer (Figure 2). This may be due to the significant increase in spike length, number of seeds per spike, number of effective tillers, 1000 grain weight, Number of grain per spike and grain yield by NPSB and NP fertilizer contributed for the significant increase in total biomass under two types of fertilizers than NPS and control fertilizer. The result is in agreement with the finding by Fayera *et al.* (2014) who reported that above ground dry biomass yield of teff was significantly influenced by application of blended fertilizer. The other report Shiferaw (2012) also indicated that above ground dry biomass yield was significantly affected by application of blended fertilizer and NP.

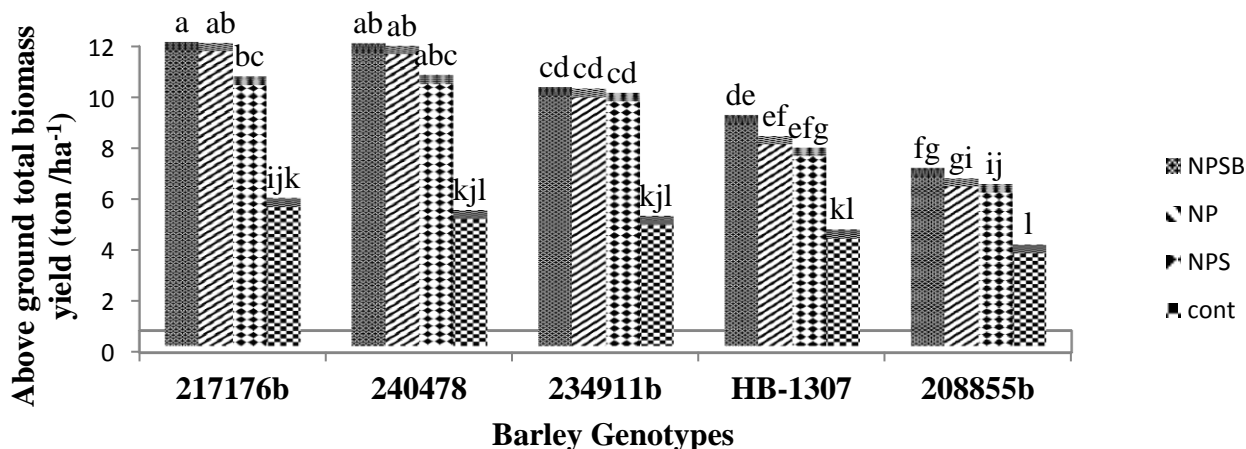


Figure 2: Interaction effects of barley genotypes and inorganic fertilizer types with regard to above ground biomass yield (ton ha⁻¹).

4.4.2. Grain Yield

The analysis of variance revealed that, significant ($P \leq 0.001$) difference due to interaction effects of genotypes by types of inorganic fertilizers on grain yield (Figure 3). Genotype 217176b with NPSB fertilizer exhibited the highest grain yield (4.9 ton ha⁻¹) which had no significant difference with yield obtained under NP fertilizer with same genotype (4.72 ton ha⁻¹) and the yield from genotype 240487 with NPSB fertilizer (4.58 ton ha⁻¹). On the other hand, lower grain yields of 1.02, 1.13 and 1.2 ton ha⁻¹, were recorded from genotype 208855b, 234911 and cultivar HB-1307, respectively with control.

NP is an excellent source of P and N for plant nutrition and it is good soluble and thus dissolves quickly in soil to release plant available phosphate and ammonium. Due to application of DAP, the content of phosphorus that added to soil is increased rather than phosphorus in NPS, which alleviate Al toxicity. In this regard, the addition of P alleviates Al toxicity by increasing root growth and nutrient uptake that lead to enhanced grain yield. This conform the findings of Rut *et*

al. (2019) who recorded similar yields from application of recommended NP and NPSB on wheat varieties. Iqbal (2013) observed that P content in wheat seedlings largely reduced by Al stress ($150 \text{ mg AlCl}_3 \text{ kg}^{-1}$ soil) while conversely pH level is found to be balanced and P level is increased after addition of exogenous P to soil. Chen *et al.* (2012) provided a threshold of P for alleviating Al toxicity based on tested plants, and indicated that if the value of P/Al molar ratio exceeds five in the root cells, Al toxicity could be alleviated.

These inferences are in accordance with the Moeinian *et al.* (2011) that believe boron application has a key role in plant metabolism, root growth will increase and by better use of nitrogen and synthesis of more carbohydrates and proteins and plants use water more efficiently. Feyera *et al.* (2014) reported that the agronomic performance was improved through application of blend of macro with micronutrient in a suitable fertilizer in nutrient deficient soil, as a result improved nutrient use efficiency of teff which increased the grain productivity. In this experiment, presence of boron in NPSB formulation did not lead to a significantly different improvement in grain yield compared to NP alone.

It seems that the presence of S in NPS formulation has depressed yield while presence of boron had promoting effect on performance especially compared to NPS. The ion SO_4 -form of sulfur is negatively charged and is retained better by acidic soils. It is important to remember that when elemental sulfur is added to soil, it creates sulfuric acid (lowering pH) and sulfur cannot be easily incorporated to soil after plants are sown and surface applied sulfur provides some pH reduction. During application to acidic soils, the soil adjacent to the granule will also be acidified slightly and affect crop roots interception restricting phosphorus and nitrogen uptake.

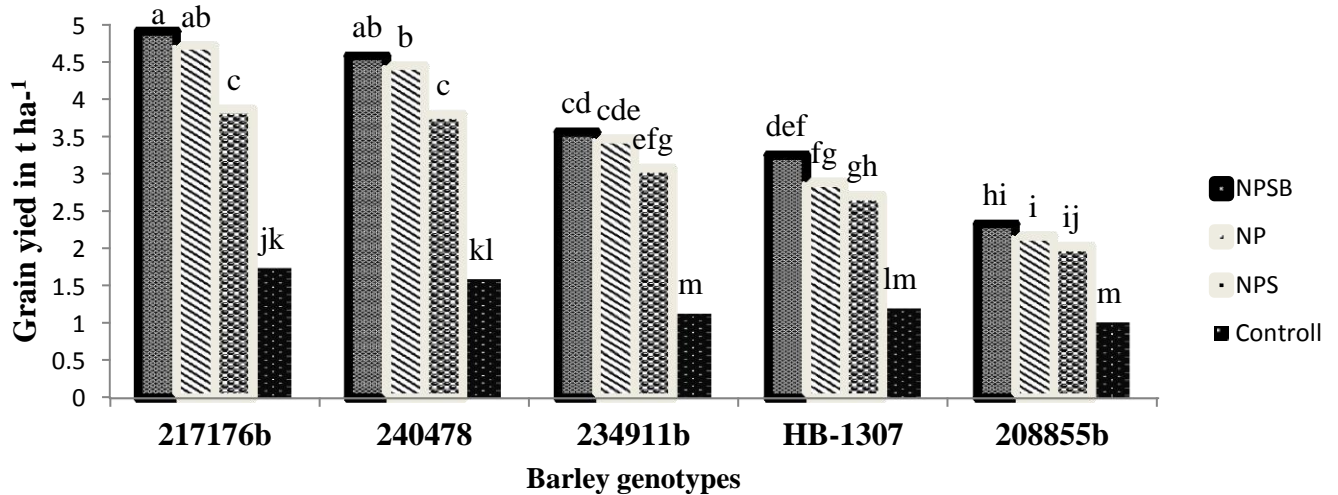


Figure3: Interaction effects of barely genotypes and inorganic fertilizer application with regard to grain yield (ton ha⁻¹).

4.4. 3. Straw Yield

The analysis of variance showed that straw yield of barley was significantly influenced ($P \leq 0.001$), due to main effects of genotypes and different types of inorganic fertilizers but not by the interaction effect (Table 9). Significantly higher straw yields were obtained from genotypes 240478, 217176b and 234911b without statistical difference among them. Whereas the lowest straw yields (3.7325ton ha⁻¹) was recorded from genotype of 208855. All fertilizer types gave significantly greater straw yields compared to the control fertilizer and there was no statistical difference among the effects of NP, NPS and NPSB. It suggests that uniform application of nitrogen in three types of fertilizers enhances the vegetative growth of barley crop that delays senescence which ultimately increase biological yield. In agreement with this report, Amsal *et al.* (2000) reported that N significantly enhanced the straw yield of wheat, since N usually promotes the vegetative growth of a plant.

4.4.4. Harvest Index

Analysis of variance indicated that the harvest index was significantly ($p \leq 0.001$) affected by genotypes and inorganic fertilizers. But, interaction effects were not significant ($p \geq 0.05$) (Table 9). Harvest index is the ratio of grain yield to the aboveground biomass yield expressed as coefficient of effectiveness. Thus, harvest index is the balance between the productive part of the plant and the reserve which form the economic yield. Genotypes 217176b and 240487 produced greater harvest indices without statistical difference between them. Whereas, the lower harvest indices of 32.025 and 33.208 % were recorded from genotype 234911b and 208855b, respectively. There was variation in harvest index of different barley genotypes due to barley inherent variability. Harvest index as a quantitative trait is an indicator of plant efficiency to distribute dry matter to grain (Shahryari and Mollasadeghi, 2011).

In response to fertilizer, greater harvest indices of 38.6% and 37.7% were obtained from applications of NPSB and NP fertilizer, respectively (Table 9). Riggs *et al.* (1981) reported a high significant and positive relation between harvest index and grain yield in barley. The lowest HI (28.10%) was obtained from the zero fertilizer. These results were supported by the findings of Harfe. (2017) who reported that minimum harvest index from control plot.

Table 9: Main Effect of Barley Genotypes and Types of Inorganic Fertilizers on Straw Yield and Harvest Index under Acidic Soil of Hagereselam.

Fertilizers	Straw yield ton ha ⁻¹	Harvest index (%)
NPSB	5.908a	38.593a
NP	5.8147a	37.69ab
NPS	5.60a	35.487b
control	3.2687b	28.993c
Fertilizer	***	***
LSD	0.56	2.96
Genotypes		
217176b	5.88a	38.63a
240478	5.93a	37.38ab
234911b	5.65a	32.025c
208855b	3.7325c	33.208c
HB- 1307	4.54b	34.767bc
Genotype	***	***
LSD	0.62	3.32
Fertilizer X genotypes	NS	NS
CV	14.71	11.42

Means followed by the same letters are not significantly different at ($p \leq 0.05$).

4.5. Grain Yield Response Index

Grain yield response index (GYRI) was calculated at control and recommended rate of NPSB. GYRI indicated the relative efficiency of barley genotypes for producing higher grain yield at control (0) fertilizers and their response to NPSB fertilizer. Accordingly, it is possible to classify barley genotypes into four groups: (i) efficient and responsive (ER) that produce high grain yield at 0 fertilizers as well as for application of recommended NPSB; (ii) efficient and not responsive

(ENR) that produce high grain yield at zero fertilizer with lower response to application of recommended NPSB than ER; (iii) not efficient but responsive (NER) that has low grain yield with response to recommended NPSB fertilizer; and (iv) neither efficient nor responsive (NENR) that has low grain yield with low response to the application of recommended NPSB fertilizer.

Barley genotype 217176b and 240478 (Figure 4) belongs to ER group, which exceeded the averages of grain yield at zero fertilizer application and GYRI, while genotypes 234911b and variety HB- 1307 were NER being with lower grain yield at zero fertilizer and higher GYRI than the average. Barley genotype 208855b was NENR, where both grain yield at zero fertilizer and GYRI were lower than the averages. According to GYRI parameter, results indicated clearly considerable differences among barley genotypes for absorbing and utilizing nutrients from deficient soils.

Genotypes 217176b and 240478 exhibited less reduction in yield under low nutrient availability soil (under acidic soil) indicating the significance of focusing on these two genotypes as an efficient gene pool to incorporate the adaptation for low nutrient availability (in the acidic soil) and with high efficiency in the utilization of N, P, S and B fertilizer applied. This is also true for application of NP fertilizer since the genotypes produced comparative yields under NPSB and NP fertilizer types. At low nutrient supply, differences among genotypes for GYRI were largely due to variation in utilization of accumulated nutrient, but with high nutrient, they were largely due to variation in uptake efficiency. It should be concluded that nutrient availability in the soil could be manipulated together with the genetic diversity of the crop as a breeding tool for barley cultivars development through improving nutrient uptake and/or utilization efficiency.

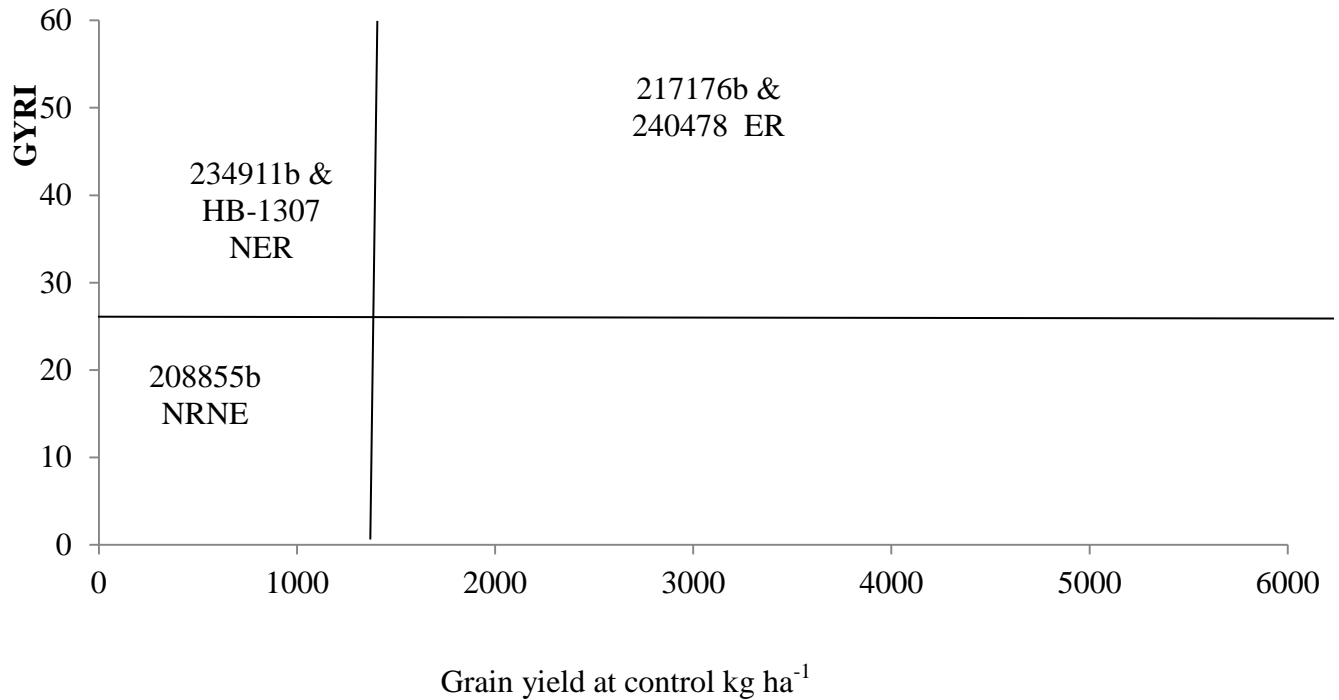


Figure 4: Grain Yield Response Index

Where: *GYRI*: grain yield response index, *ER*: efficient and responsive, *NER*: not efficient and responsive and *NENR*: not efficient and not responsive.

4.6 Correlations

The correlation coefficient result indicated that grain yield had highly significant and positively association with number of effective tillers ($r = 0.88$ ***), spikes length ($r = 0.81$ ***), number of grain per spike ($r = 0.86$ ***), aboveground dry biomass mass yield ($r = 0.95$ ***), straw yield ($r = 0.84$ ***), grain weight ($r = 0.94$ ***) and harvest index ($r = 0.76$ ***) (Table 10). The results on the association of grain yield with aboveground dry biomass yield in this study agreed with the findings of Gebreyes (2008) who reported that grain yield was positively and highly significantly associated with total above ground biomass of wheat. Similarly, grain yield had positively association with plant height ($r = 0.90$ ***). Plant height was positively correlation with aboveground dry biomass yield ($r = 0.84$ ***), spike length ($r = 0.87$ ***), number of

grain per spike ($r=0.83^*$), effective tillers per plant ($r=0.91^{***}$), thousand grain weight ($r=-0.88^{***}$) and harvest index ($r = 0.68^{***}$). However, grain yield was negatively and significantly correlated with date of emergence ($r = -0.55^{***}$), date of heading ($r = -0.57^{***}$), and date of physiological maturity ($r = -0.53$).

Table10: Correlation Coefficients between Mean Agronomic Traits of Barley Genotypes Grown With Types of Inorganic Fertilizers under Acidic Soil at Hagerselam

	DE	DH	DPM	PH	NET	SL	NGS	AGBM	GY	SY	TGW
DE	1000										
DH	0.89 ^{***}	1000									
DM	0.79 ^{***}	0.93 ^{***}	1000								
PH	-0.68 ^{***}	-0.72 ^{***}	-0.68 ^{**}	1000							
NET	-0.74 ^{***}	-0.72 ^{***}	-0.66 ^{***}	0.91 ^{**}	1000						
SL	-0.69 ^{***}	-0.74 ^{***}	-0.7 ^{***}	0.87 ^{***}	0.81 ^{***}	1000					
NG	-0.68 ^{***}	-0.64 ^{***}	-0.58 ^{***}	0.83 ^{***}	0.92 ^{***}	0.80 ^{***}	1000				
BY	-0.49 ^{***}	-0.58 ^{***}	-0.54 ^{***}	0.84 ^{***}	0.84 ^{***}	0.77 ^{***}	0.84 ^{***}	1000			
GY	-0.53 ^{***}	-0.57 ^{***}	-0.53 ^{***}	0.9 ^{***}	0.88 ^{***}	0.81 ^{***}	0.86 ^{***}	0.95 ^{***}	1000		
SY	-0.43 ^{**}	-0.54 ^{***}	-0.52 ^{***}	0.73 ^{***}	0.76 ^{***}	0.68 ^{***}	0.76 ^{***}	0.97 ^{***}	0.84 ^{***}	1000	
TGW	-0.43 ^{**}	-0.52 ^{***}	-0.49 ^{***}	0.88 ^{***}	0.80 ^{***}	0.81 ^{***}	0.79 ^{***}	0.91 ^{***}	0.94 ^{***}	0.82 ^{***}	1000
HI	-0.35 ^{**}	0.34 ^{***}	-0.29 ^{**}	0.68 ^{***}	0.61 ^{***}	0.59 ^{***}	0.59 ^{***}	0.54 ^{***}	0.76 ^{***}	0.33 ^{**}	0.72 ^{***}

*DE = date of emergence, DH = date of heading, DM = date of maturity, PH= plant height, NET= number of effective tillers M², SL= spike length, NGS= number of grain spike⁻¹, AGBY = above ground biomass yield, GY= grain yield, SY= straw yield, TGW= thousand grain weight and HI= harvest index. *, ** and *** = significantly different at 0.05, 0.01, 0.001 probability levels respectively.*

4.7. Economic Analysis

In the result of present study, the costs of fertilizers, urea, NP, NPS and NPSB, labor costs for agronomic practice were used for the analysis. To identify treatments with the optimum return to the farmers' investment, marginal rate of return analysis was performed on non-dominated treatments. According to CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be 100% for acceptance.

Partial budget analysis of the combination of barley genotypes with different types of fertilizers was presented in Tables 11 and 12. The highest net benefit of ETB 59932.75 ha⁻¹ and marginal rate return of 3745.35% with value to cost ratio of ETB 10.32 per unit of investment were obtained from combination of genotype 217176b with NPSB for barley production. This was followed by net benefit of ETB 55700.5 ha⁻¹ and marginal rate of return of 3664.28 % with value to cost ratio of ETB 9.7 per unit of investment from combination of barley genotype 240478 and NPSB. This means that for every 1.00 birr invested for NPSB fertilizer, for barley genotypes 217176 and 240478 in the field, producers can expect to recover 1.00 Birr and obtain an additional of 37.45 and 36.64 Birr, respectively (Table 12).

Similarly, the genotype 217176b with application of NP gave a comparatively high net benefit and MRR well above the threshold level for acceptance. Moreover, genotype 240478 either with NPSB or NP fertilizer provided adequately high net benefit and MRR much greater than the minimum required 100%. Therefore, the combination of genotype 217176b and 240478 with either NPSB or NP were economically feasible for barley production under Acidic soil of Hagerselam.

Table 11: Partial Budgets and Dominance Analysis of Barley Genotypes Yield Influenced By Types of Inorganic Fertilizer Application

Treatments	Average grain yield (ton ha ⁻¹)	Adjusted grain yield (ton ha ⁻¹)	Gross field benefits (Birr ha ⁻¹)	Total variable cost (Birr ha ⁻¹)	Net benefits (Birr ha ⁻¹)	Dominance
control 208855b	1.01	0.909	12953.25	1338	11615	-
HB-1307	1.2	1.08	15390	1541	14052	-
234911b	1.13	1.017	14492.25	1545	13154.25	D
240478	1.59	1.431	20391.75	1767	19053.75	-
217176b	1.74	1.566	22315.5	1889	20977.5	-
NPS 208855b	2.03	1.827	26034.75	2568	23466.75	-
HB-1307	2.71	2.439	34755.75	2875	32187.75	-
234911b	3.08	2.772	39501	3089	36933	-
240478	3.8	3.42	48735	3396	46167	-
217176b	3.87	3.843	54762.75	3587	52194.75	-
NP 208855b	2.17	1.953	27830.25	3592	25000.25	D
HB-1307	2.89	2.601	37064.25	3895	34234.25	-
234911b	3.47	3.123	44502.75	4163	41672.75	-
240478	4.45	4.005	52071.25	4394	49241.25	-
217176b	4.72	4.248	60534	4645	55889	-
NPSB 208855b	2.33	2.097	29882.25	4652	26844.25	D
HB-1307	3.25	2.925	41681.25	5127	38643.25	-
234911b	3.56	3.204	45657	5339	42619	-
240478	4.58	4.122	58738.5	5696	55700.5	-
217176b	4.91	4.419	62970.75	5809	57161.75	-

Table 12: Marginal Analysis of Barley Genotypes Yield Influenced With Types of Inorganic Fertilizers.

Treatments		Total variable cost (Birr ha ⁻¹)	Net benefits (Birr ha ⁻¹)	Marginal variable cost	Marginal net benefits (Birr ha ⁻¹)	Marginal Rate of Return%
control	208855b	1338	11615			-
	HB-1307	1541	14052	203	2437	1200.98
	234911b	1545	13154.25	-	-	D
	240478	1767	19053.75	222	5899.5	2657.43
	217176b	1889	20977.5	122	1923.75	1576.84
NPS	208855b	2568	23466.75	679	2489.25	366.6
	HB-1307	2875	32187.75	307	8721	2840.71
	234911b	3089	36933	214	4745.25	2217.40
	240478	3396	46167	307	9234	3007.81
	217176b	3587	52194.75	191	6027.75	3155.89
NP	208855b	3592	25000.25	-	-	D
	HB-1307	3895	34234.25	303	9234	3047.52
	234911b	4163	41672.75	268	7438.5	2775.59
	240478	4394	49241.25	231	7568.5	3276.40
	217176b	4645	57704	251	8462.75	3371.61
NPSB	208855b	4652	26844.25	-	-	D
	HB-1307	5127	38643.25	475	11799	2484
	234911b	5339	42619	212	3975.75	1875.35
	240478	5696	55700.5	357	13081.5	3664.28
	217176b	5809	59932.75	113	4232.25	3745.35

N.B: Prices of Urea: 13.38 birr/kg, NPS: 12.30, DAP: 14.92 birr/kg NPSB: 15.52, Price of barley: 14.25 birr/kg, Family labor cost was assigned and different labor time and cost was used on each treatment based on yield increment.

5. SUMMARY AND CONCLUSION

The experiment was conducted on farmer training field at Hagereselam, Southern Ethiopia to determine the response of barley genotypes to inorganic fertilizers types under acidic soil. The factorial combinations of four fertilizer types (Control, NP, NPS and NPSB) and five barley genotypes (217176b, 240478, 234911b, 208855b and variety HB- 1307) were laid out in a randomized complete block design with three replications.

The soil of the experimental field was clay loam in texture with a pH of 4.48 which was strong acidic and availability of most essential nutrients are low and crop respond to exogenous application of nutrients.

The phenological and growth parameters showed significant differences due to the main effects of barley genotypes and types of inorganic fertilizers treatments and the interaction effect. The results showed that day to emergence significantly ($P < 0.001$) affected by the main effect of barley genotypes and day to heading was significantly ($P < 0.001$) affected by the main effect of barley genotypes and inorganic fertilizers. But day to physiological maturity was affected by interaction effect of genotypes to fertilizers types under acidic soil.

The analysis of variance showed significant differences ($P < 0.001$) on plant height and number of effective tillers per m^2 due to interaction effect. The tallest plant height was recorded from genotype 217176b at NPSB, NP and NPS respectively without significant difference among each other and also genotype 240478 with NPSB.

The results revealed highly significant ($P \leq 0.001$) to interaction effects of genotypes with different types of inorganic fertilizers on effective tiller number. The highest mean number of

effective tillers m^{-2} 69.33, 65.33 and 62.3 were recorded from genotype 217176b treated with recommended NPSB, NP and NPS respectively without statically difference among each other and also genotype 240478 with NPSB.

Spike length was significantly ($p < 0.001$) influenced by the main effects of types of inorganic fertilizers and genotypes. Genotypes 217176b and 240478 produced longer spike length 10.98 and 10.33cm respectively with no significant difference between them. The highest spike lengths 9.91 and 9.43 cm were recorded from the plot treated with recommended NPSB and NP application without significant difference among each other. The highest mean numbers of grain per spike 46.23 was recorded from genotype 217176b. Genotypes 217176b produced the highest thousand-grain weight (38.03g).The highest mean thousand-grain weight 37.51 and 36.22 g were obtained from recommended rate of NPSB and NP respectively without statistically significance among each other.

The significantly higher biomass yields were obtained from genotypes 217176b and 240478 with application of NPSB and NP fertilizers without statistical difference among these treatments. Genotype 217176b with NPSB fertilizer gave the highest grain yield (4.9 ton ha^{-1}) but was statistically not par with that obtained under NP fertilizer with same genotype (4.72 ton ha^{-1}). This also had no significant difference with grain yield obtained from genotype 240478 with NPSB fertilizer (4.58 ton ha^{-1}). The significantly higher straw yields 5.9342, 5.8825 and 5.65 ton ha^{-1} was obtained from genotypes 240478, 217176b and 234911b without statistical difference among them. All fertilizer types gave significantly greater straw yields, as compared to the zero fertilizer and there was no statistical difference among the straw yield recorded from NP, NPS and NPSB. Genotypes 217176b and 240478 produced greater harvest indices without statistical

difference between them. Similarly greater harvest indices were obtained from applications of NPSB and NP fertilizer.

Barley genotypes 217176b and 240478 belong to ER, while genotypes 234911b and variety HB-1307 were NER. But Barley genotype 208855b was NENR. Grain yield had highly significant positive association with number of effective tillers, spikes length, number of grain per spike, aboveground dry biomass mass yield, straw yield, number of 1000 grain weight and harvest index.

The economic analysis revealed that highest net benefit of Birr 59932.75 Birr ha⁻¹ was obtained from application of recommended rate of NPSB fertilizer for genotypes 217176b. The highest marginal rate of return (MRR %) 3745.35 was recorded from the application of recommended rate of NPSB fertilizer for genotype 217176b. Similarly, the same genotype with application NP gave a comparatively high net benefit and MRR well above the threshold level for acceptance. Moreover, genotype 240478 either with NPSB or NP fertilizer provided adequately high net benefit and MRR much greater than the minimum required 100%. Given the fact that grain yield performance between the two varieties in combination with either NPSB or NP is not statistically significant, either of the two genotypes with the recommended rates of NPSB or NP fertilizer can be used for production of barley in acidic soils of Hageresalam and acidic soils of similar agro-ecologies in the highlands of Ethiopia. The experiment did not show adequate evidence to favor use of NPSB in preference to NP. However, it would be too early to reach at a conclusive recommendation, since the current study was carried out only in one location and one cropping season. Further studies that are replicated at least over seasons are needed to investigate response of the two promising barley genotypes to application of inorganic fertilizers under acidic soil conditions in order to come up with a conclusive recommendation.

6. REFERENCES

- Abreha Kidanemariam, Heluf Gebrekidan, Tekalign Mamo and Kindie Tesfaye (2013). Wheat crop response to liming materials and N and P fertilizers in acidic soils of Tsegede highlands, northern Ethiopia. *Agriculture, Forestry and Fisheries*, 2(3): 126-135. doi: 10.11648/j.aff.20130203.12. Accessed on March 16, 2014. Accessed on March 10, 2014.
- Achalu C, Heluf G, Kibebew K, Abi T (2012). Response of barley to liming of acid soils collected from different land use systems of Western Oromia, Ethiopia. *J. Biodiv. Environ. Sci.* 2(7):1-13.
- AderaSisay 2016. Response of Tef (*Eragrostistef*) to different blended fertilizer rates on vertisols in Jama District, North-eastern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.
- Agegnehu, G., and Sommer, K (2000a). Optimization of the efficiency of phosphate fertilizers in acidicferralitic soils of the humid tropics. *Ethiopian Journal of Natural Resources* 2, 63-77.
- Agegnehu, G., and Sommer, K (2000b). Optimization of the efficiency of phosphate fertilizers in acidicferralitic soils of the humid tropics. *Ethiop. J. Nat. Resources* 2, 63 -77.
- Ahmed O.H., Majid N.M.A (2014). Improving phosphorus availability in an acid soil using organic amendments produced from agro industrial wastes. *Sci. World J.* 2014;2014:506356.

- Alam MZ, SA Haider (2006). Growth attributes of barley (*Hordeum vulgare* L.) cultivars in relation to different doses of nitrogen fertilizer. *Journal of Life Earth Science*. 1: 77-82.
- Alam, M. Z., Haider, S. A. and Paul, N. K (2007). Yield and Yield Components of Barley (*Hordeum vulgare* L.) cultivars in Relation to Nitrogen Fertilizer. *Journal of Applied Sciences Research*. 3(10): 1022-1026.
- Al-Turki, A. I. and M. I. D. Helal (2004). Mobilization to Pb, Zn, Cu, and Cd, in polluted soil. *Pak. J. Biol. Sci.* 7:1972-1980.
- Amsal, T. and D. Tanner (2001). Effect of fertilizer application on N and P uptake, recovery and use efficiency of bread wheat grown on two soil types in central Ethiopia. *Ethiopian Journal of Natural Resources*. 3(2): 219-244. and N and P fertilizers in acidic soils of Tsegede highlands, northern Ethiopia. *Agriculture*,
- Araya Alemie, Solomon Habtu, Mitiku Haile, Sisay F. and TadesseDejenie (2011). Determination of Local Barley (*Hordeum Vulgare*) Crop Coefficient and Comparative Assessment of Water Productivity for Crops Grown Under the Present Pond Water in Tigray, Northern Ethiopia
- Arquero O., D. Barranco and M. Benlloch (2006). Potassium starvation increases stomatal conductance in olive trees. *Horticultural Science*, 41(2): 433-436.
- Beena S., Hasina G, Amir Z. k., Nishat L. B. and Ayub K (2012). Growth factors and straw yield of wheat cultivars in reation with Nitrogen and sulfur fertilization. *ARP journal of Agricultural and biological science*. Vol.7, No 1:13-21
- Benton, J.J (2003). *Agronomic Hand Book Management of Crops, Soils, and their Fertility*.

- Berhan Abayu (2012). Agronomic and Economic Effects of Blended Fertilizers Under Planting Method On Yield And Yield Components of Tef: M.Sc Thesis, Mekelle University, Mekelle, Ethiopia.
- Blagoeva, V., Iliev, E. and Nikolova, E (2004). Potatoes–cultivation, diseases and pests, and storage .*Publisher “Enjovche” Sofia*, 105 p.
- Bolland M, Gazey C, Miller A, Gartner D and Roche J (2004). Department of Agriculture and Food, Western Australia Bulletin 4602. (online)
- Bona L, Wright RJ, Baligar VC, Matuz J (1993). Screening wheat and other small grains for acid soil tolerance. *Landscape and Urban Planning*. 1993;27 (2-4):175–178.
- Bouyoucos, G. J (1962). Hydrometer method improved for making particle size analysis of soil. *Agronomy Journal*, 54: 464-465.
- Brady D.J., Edwards D.G., Asher C.J., Blamey F.P.C (1993). Calcium amelioration of aluminum toxicity effects on root hair development in soybean [*Glycine max* (L.) Merr.] *New Phytol*. 1993; 123:531–538.
- Brady, N., and Weil, R (2016). “The nature and properties of soils,” Pearson Education, Columbus, EUA. Sumner, M.E., 2000. *Handbook of Soil Science*. CRC Press Washington, D.C. USA.
- Brady, N.C. and Weil, RR (2002). *The nature and properties of soils thirteenth edition* Prentice Hall, New Jersey.
- Bray RH, Kurz LT (1945). Determination of total, organic and available forms of phosphorous in soil. *Soil Sci* 59(1): 39-45.
- Burkus Z. and Temelli F (2005). Rheological properties of barley β -glucan. *Carbohydrate Polymers* 59(4): 459-465.

- Chapman HD (1965). Cation exchange capacity. In: C.A. Black, L.E. Ensminger and F.E. Clerk (Eds). *Methods of soil analysis*. American society of Agronomy, 9:891-901.
- Chen R.F., Zhang F.L., Zhang Q.M., Sun Q.B., Dong X.Y., Shen R.F (2012). Aluminium-phosphorus interactions in plants growing on acid soils: Does phosphorus always alleviate Aluminium toxicity? *J. Sci. Food Agric.* 2012;92:995–1000.
- Chen Z.C., Liao H (2016). Organic acid anions: An effective defensive weapon for plants against aluminum toxicity and phosphorus deficiency in acidic soils. *J. Genet. Genom.* 2016;43:631-638. doi: 10.1016/j.jgg.2016.11.003.
- CIMMYT (1988). *From Agronomic data to Farmer Recommendations: An Economic work Book*. Mexico, D.F.: CIMMYT.
- CIMMYT (1998). *International maize and wheat improvement Center from agronomic data to farmers recommendations. Economics training manual. Completely revised edition*. D. F. Mexico.
- Collard B.C.Y., Mackill D.J (2008). Marker-assisted selection: An approach for precision plant breeding in the twenty-first century. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 2008;363:557–572. doi: 10.1098/rstb.2007.2170. Collected from different land use systems of Western Oromia, Ethiopia. *Journal of crop yield. Experimental Agriculture* 40:369-379.
- CSA (Central Statistical Agency) (2012). *Agricultural sample survey for the 2011/2012 crop season. Volume I Report on Area and production of major crops private peasant holdings, meher season (September – December 2011)*. Statistical Bulletin, FDRE/CSA, Addis Ababa, Ethiopia.

- CSA (Central Statistical Agency) (2014). Agricultural sample survey: area and production of major crops, Meher season. Vol. I. Addis Ababa, Ethiopia.
- CSA (Central Statistical Agency) (2018). Central Statistical Agency agricultural sample survey report on area and production of major crops private peasant holdings, meher season. Addis Ababa, Ethiopia. Volume I.
- Dagne W; Habtamu Z; Demissew A; Temam H; Harjit S (2008). The Combining ability of Maize Inbred lines for grain yield and reaction to Gray leaf spot disease. *East African Journal Sciences* 2(2):135-145.
- Dai, H. X., Cao, F. B., Chen, X. H., Zhang, M., Ahmed, I. M., Chen, Z. H (2013). Comparative proteomic analysis of aluminum tolerance in Tibetan wild and cultivated barleys. *PLoS ONE* 8:e63428.
- Dawood M., Cao F., Jahangir M.M., Zhang G., Wu F (2012). Alleviation of aluminum toxicity by hydrogen sulfide is related to elevated *ATPase*, and suppressed aluminum uptake and oxidative stress in barley. *J. Hazard. Mater.* 2012;209–210:121–128. doi: 10.1016/j.jhazmat.2011.12.076.
- Debnath, M.R., Jahiruddin M., Rahman, M.M. and Haque, M.A (2011). Determining optimum rate of boron application for higher yield of wheat in Old Brahmaputra Flood plain soil. *J. Bangladesh Agril. Univ.* 9(2): 205–210.
- DebituTola (2013). Soil fertility characterization and evaluation of blended fertilizer for wheat (*Triticumaestivum* L.) production on vertisols of Woliso district, South Western Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

- Dejene K. and Fetien A (2014). Growth and yield of barley (*Hordeum vulgare* L.) as affected by nitrogen and phosphorus fertilization and water regimes in Tigray, Ethiopia. *Momona Ethiopian Journal of Science (MEJS)*, V6(1):45-57
- Dewal, G. S. and Pareek R. G (2004). Effect of phosphorus, Sulphur, and zinc on growth, yield and nutrient uptake of wheat (*Triticumaestivum* L.). *Indian J. Agronomy*. 49: 160-162.
- Dixit G., Singh A.P., Kumar A., Mishra S., Dwivedi S., Kumar S., Trivedi P.K., Pandey V., Tripathi R.D (2016). Reduced arsenic accumulation in rice (*Oryza sativa* L.) shoot involves sulfur mediated improved thiol metabolism, antioxidant system and altered arsenic transporters. *Plant Physiol. Biochem.* 2016;99:86–96. doi: 10.1016/j.plaphy.2015.11.005.
- Ebert, G (2009). Potassium nutrition and its effect on quality and post harvest properties of potato. Proceedings of the International Symposium on Potassium Role and Benefits in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damages 1: 637- 63809.
- Ethiopian Soil Information System (EthioSIS) (2013). Towards improved fertilizer recommendations in Ethiopia-Nutrient indices for categorization of fertilizer blends from Ethio SIS woreda soil inventory data. Addis Ababa, Ethiopia.
- Ethio SIS (Ethiopian Soil Information System) (2014). Soil Fertility and fertilizer recommendation Atlas of Tigray Region. Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA).
- Ezaki B, Gardner RC, Ezaki Y, Matsumoto H (2000). Expression of aluminum-induced genes in transgenic Arabidopsis plants can ameliorate aluminum stress and/or oxidative stress. *Plant Physiol.* 2000;122(3):657–665. doi: 10.1104/pp.122.3.657.

- Fageria, N. K., and Nascente, A. S (2014). Management of soil acidity of South American soils for sustainable crop production. *Adv. Agron.* 128, 221-275.
- Fageria N. K. and V. C. Baligar (2003). Fertility Management of Tropical Acid Soils for Sustainable Crop Production. pp. 332-334. *In: ZdenkoRengel, (eds) Soils for Sustainable Crop Production: Handbook of Soil Acidity.* New York, USA.
- FayeraAsefa, AdugnaDebela and Muktar Mohammed (2014). Evaluation of Tef [*Eragrostis tef* (zuccagni). Trotter] Responses to Different Rates of NPK Along With Zn and B in Didessa District, South western Ethiopia. *World Applied Sciences Journal*, 32 (11): 2245-2249
- Firehiwot Getachew (2014). Effect of vermicompost and inorganic N and P fertilizers on growth, yield, and quality of bread wheat (*Triticum aestivum* L.) in eastern Ethiopia M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.
- FissehaHadgu (2008). Study on the Response of Bread Wheat (*Triticum Aestivum*) to Urea and Dap Fertilizer on Cambisol at SamreTigray north Ethiopia. unpublished report. *Forestry and Fisheries*, 2(3): 126-135. doi: 10.11648/j.aff.20130203.12. Accessed on March
- Foy, C. D (1983). The physiology of plant adaptation to mineral stress. *Iowa State J. Res.* 57, 355–391.
- Franklin, O., Cambui, C. A., Gruffman, L., Palmroth, S., Oren, R. and Nasholm, T (2017). The carbon bonus of organic nitrogen enhances nitrogen use efficiency of plants, 25–35. <https://doi.org/10.1111/pce.12772>.

- Furukawa, J., Yamaji, N., Wang, H., Mitani, N., Murata, Y., Sato, K (2007). An aluminum-activated citrate transporter in barley. *Plant Cell Physiol.* 48, 1081–1091.
- GebreyesGurmu (2008). Soil Fertility Characterization and Response of Durum Wheat to Nitrogen and Phosphorus Fertilization on Vertisol at Enewari, North eastern Ethiopia.M.Sc. Thesis in Agriculture (Soil Science). Haramaya University, Haramaya, Ethiopia.
- Getaneh W (2007). The barley leaf rust in the high land of Ethiopia: Significance ,virulence spectrum and sources of partial resistance. PhD Dissertation, Haramaya University, Ethiopia.
- GirmaMegersa (2014). Genetic erosion of barley in North Shewa Zone of Oromiya Region, Ethiopia. *International Journal of Biodiversity and Conservation* Vol. 6(3), pp. 280-289, March 2014
- Gong, W.; Yan, X.; Wang, J.; Hu, T.; Gong, Y (2009): Long-term manure and fertilizer effects on soil organic matter fractions and microbes under a wheat–maize cropping system in northern China. *Geoderma* 2009, 149, 318–324.
- Grzebisz, W., Gransee, A., Szczepaniak, W. and Diatta, J.B (2013). The Effects of Potassium Fertilization on Water-Use Efficiency in Crop Plants. *Journal of PlantNutritional and Soil Science* 176(3):355-374.
- Guo P., Li Q., Qi Y.-P., Yang L.-T., Ye X., Chen H.-H., Chen L.-S (2017). Sulfur-mediated-alleviation of aluminum-toxicity in *Citrus grandis* seedlings. *Int. J. Mol. Sci.* 2017;18:2570. doi: 10.3390/ijms18122570.
- Gupta N., Gaurav S.S., Kumar A (2013). Molecular basis of aluminium toxicity in plants: A review. *Am. J. Plant Sci.* 2013;4:21–37. doi: 10.4236/ajps.2013.412A3004.

- Gupta U.C., Jame Y.W., Campbell C.A., Leyshon A.J., Nicholaichuk W (1985). Boron toxicity and deficiency: A review. *Can. J. Soil Sci.* 1985;65:381–409. doi: 10.4141/cjss85-044.
- Gupta VK, Kumar S, Singh AK (2004). Yield and quality of wheat (*Triticumaestivum*) as influenced by sulphur nutrition and weed management. *Indian J. Agric. Sci.* 74(5): 254-256.
- Habtamu A, Heluf G, Bobe B, Enyew A (2001). Effects of Organic and Inorganic Fertilizers on Yield and Yield Components of Maize at Wujiraba Watershed, Northwestern Highlands of Ethiopia. *Ame J Plant Nutrition Fertilization Technol* 5(1): 1-15.
- HailuGebre-Mariam (2014). Effect of blended fertilizer application on basic soil physicochemical property, yield components of wheat (*Triticumaestivum* L.) and its economic profitability in oflaworeda highlands of southern Tigray, Ethiopia, Mekell University.
- Harfe, M. (2017). Response of bread wheat (*Triticumaestivum*) varieties to N and P fertilizer rates in Ofla District, Southern Tigray, Ethiopia. *African journal agricultural research*, 12 (19) 1646-1660.
- Harlan, Jack R., and Daniel Zachary (1966). *Distribution of wheat and barley*. Science 153.1074-80.
- Hartmann, H.T., Kofranek, AM., Rubatzky, V.E. and Flocker, WJ (1988). *Plant science. Growth, Development, and Utilization of cultivated plants*. Prentice Hall career and Technology New Jersey.
- Havlin, J.L., Beaton, J.D., Tisdale, S.L. and Nelson, W.L (1999). *Soil fertility and fertilizer:an introduction to nutrient management* Prentice Hall, New York, 499p.

- Hossain M, Zhou MX, Mendham NJ (2005). A reliable screening system for aluminium tolerance in barley cultivars. *Aust J Agric Res.* 2005;56 (5):475–482. doi: 10.1071/AR04191
- Iqbal M.T (2013). Phosphorus enhances aluminium tolerance in both aluminium-tolerant and aluminium sensitive wheat seedlings. *S.Afr.J. Plant Soil.* 2013;30:13–21. doi: 10.1080/02571862.2013.770929
- Iuchi, S., Koyama, H., Iuchi, A., Kobayashi, Y., Kitabayashi, S., Kobayashi, Y (2007). Zinc finger protein STOP1 is critical for proton tolerance in Arabidopsis and coregulates a key gene in aluminum tolerance. *Proc. Natl. Acad. Sci. U.S.A.* 104, 9900–9905.
- Jackson, M.L (1973). *Soil Chemical Analysis*. Printice Hall. Ind, Englewood, Chiffs N.J.
- Jafarimoghadam, M.Sc thesis, Gorgan university of agriculture sciences and natural resources..(Gorgan, Iran, 2008).
- JianFeng M, Sakiko N, Kazuhiro S, Hiroyuki I, Jun F, Kazuyoshi T (2004). Molecular mapping of a gene responsible for Al-activated secretion of citrate in barley. *J. Exp. Bot.*, 55:1335-1341.
- Jones, C., Olson, R and Dinkins, C (2011). Nutrient uptake timing by crops: to assist with fertilizing decisions. Montana State University, pp 2-8.
- Kays, S, Shimizu N, Barton F, Ohtsubo K (2005). Near-Infrared transmission and reflectance spectroscopy for the determination of dietary fiber in barley cultivars. *Crop Science*, 45: 2307-2311.

- KemelewMuhe and AlemayehuAssefa (2011). Diversity and Agronomic Potential of Barley (*Hordeum vulgare* L.) Landraces in Variable Production System, Ethiopia. *World Journal of Agricultural Sciences*, 7 (5): 599-603
- Kinraide T.B., Pedler J.F., Parker D.R (2004). Relative effectiveness of calcium and magnesium in the alleviation of rhizotoxicity in wheat induced by copper, zinc, aluminum, sodium, and low pH. *Plant Soil*. 2004;259:201–208. doi: 10.1023/B:PLSO.0000020972.18777.99.
- Kochian, K. V (1995). Cellular mechanisms of aluminium toxicity and resistance in plant. *Annu. Rev. Plant Physiol. Mol. Biol.*, 46, 237-260
- Kochian, L. V., Hoekenga, O. A., and Pineros, M. A (2004). How do crop plants tolerate acid soils? Mechanisms of aluminum tolerance and phosphorous efficiency. *Annu. Rev. Plant Biol.* 55, 459-493.
- Kochian, L. V., Hoekenga, O. A., and Pineros, M. A (2004). How do crop plants tolerate acid soils? – Mechanisms of aluminum tolerance and phosphorous efficiency. *Annu. Rev. Plant Biol.* 55, 459–493. doi: 10.1146/annurev.arplant.55.031903.141655
- Ladha, J.K.; Kesava Reddy, C.; Padre, A.T.; van Kessel, C (2011): Role of nitrogen fertilization in sustaining organic matter in cultivated soils. *J. Environ. Qual.* 2011, 40, 1756–1766.
- Landon JR. 1991. *Booker Tropical Soil Manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics.* John Wiley & Sons Inc., New York.
- Landon JR (2014). *Booker Tropical Soil Manual. A handbook for soil survey and agricultural land evaluation in the tropics and sub tropics.* John Wiley and Sons, New York. P 474.

- Lawlor, D (2004). Mengel, K. and Kirkby, EA Principles of plant nutrition. Oxford University Press.
- Lima Echart C, Fernandes Barbosa-Neto J, Garvin D, Cavalli-Molina S. (2002). Aluminum tolerance in barley: Methods for screening and genetic analysis. *Euphytica*. 126: 309-313.
- Malakooti, M. J. and P. Keshavarz (2006). A view on Iran soil fertility (identification and exploitation), Sana publication. 503 p.
- Malakouti, M. J.(2008). The effect of micronutrients in ensuring efficient use of macronutrients. *Turk J. Agric.*, 32:215-220.
- Malakouti, M. J. and M. M. Tehrani (2006). Effect of micronutrients on increased yield and quality improvement of agricultural product, micro elements with macro effects 3rd edition, TarbiatModares University with cooperation of Research Institute of Water and Soil, Behran, Iran. 390 p
- Malakouti, M. J.; M. N. Gheibi, M. R. Balali and S. Divan Beigi. (2000). Effect of micronutrients on protein improvement and wheat grain enrichment in 10 provinces, Iran (part 2) Set of articles agricultural education publication. p. 379-393.
- Marschner, H (2011). “Marschners mineral nutrition of higher plants,” Academic press,London.
- Marschner, H (2002). Mineral Nutrition of Higher Plants. Second edition. Academic press, Amsterdam, Boston, Heidelberg, London, New York, Oxford, Paris, San Diego, San Francisco, Singapore, Sydney, Tokyo.
- Martin, JH, Walden RP, Stamp DL (2006). Principle of field crop production. Pearson Education, Inc.

- MasreshaMitiku (2014). Response of Maize (*Zea mays L.*) to application of Mineral Nitrogen Fertilizer and Compost in Godere District, Gambella Region, Southwestern Ethiopia. Haramaya University, Ethiopia.
- Maxim P, Duta Z (1996). Aluminium tolerance of barley 1. Efficiency of in vivo procedure in estimation of genotypic differences. *Romanian Agric Res.* 1996 ;(5-6):21–28.
- McLean, F. T., and Gilbert, B. E (1927). The relative aluminum tolerance of crop plants. *Soil Sci.* 24, 163–175.
- Melkamu H, Gashaw M and Wassie H (2019). Effects of different blended fertilizers on Yield and yield components of food barley (*Hordeum vulgare L.*) On nitisols at hulla District, southern Ethiopia. *Academic research journal.* Vol. 7 (1): 49- 58.
- Mesfin A (2007). Nature and management of acid soils in Ethiopia. Addis Ababa, Ethiopia. P 99.
- Minella E, Sorrells ME (1992). Aluminium tolerance in barley: genetic relationships among genotypes of diverse origin. *Crop Sci.* 1992;32:593–598.
- Mohammed YA, Kelly J, Chim BK, Rutto E, Waldschmidt K (2011). Nitrogen Fertilizer Management for Improved Grain Quality and Yield in Winter Wheat in Oklahoma. *Journal of Plant Nutrition*36(5): 749-761.
- Molina-Cano J, Russell J, Moralejo M, Escacena J, Arias G, Powell W (2005). Chloroplast DNA microsatellite analysis supports a polyphyletic origin for barley. *Theoretical and Applied Genetics*, 110(4): 613-619.
- Mulatu, B. &Grando, S (2011). Barley Research and Development in Ethiopia. Proceedings of the 2nd National Barley Research and Development Review Workshop. 28-30

November 2006, HARC, Holetta, Ethiopia. ICARDA, PO Box 5466, Aleppo, Syria. pp xiv + 391.

Muluken bantayehu (2013). Study on malting barley genotypes under diverse agro ecologies of north western Ethiopia: Adet agricultural research center, p. O. Box 08, Bahirdar, Ethiopia.

Nigussie A, Kissi E (2012). Physicochemical Characterization of Nitisol in Southwestern Ethiopia and Its Fertilizer Recommendation Using NuMaSS. *Glob. Adv. Res. J. Agric. Sci.* 1 66-73

Olsen, S., Cole, C., Watanabe, F., Dean, L (1954). Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. USDA Circular No.939, US Gov. Print. Office, Washington, D.C.

Ortiz-monasterio J.I., Pena R.J., Sayre K.D and Rajam S (1997). CIMMYT's genetic progress in wheat grain quality under four nitrogen rates. *Crop Science*, 37(3): 892-898.

Pahlevanrad, Gh. Keykha and M. R. Narooyirad. *J. Iranian Journal of Pajouhesh&Sazandegi*, 2008, 79, 142. Press, Washington, USA. 316p

Panhwar Q.A., Naher U.A., Radziah O., Shamshuddin J., Razi I.M (2014). Bio-fertilizer, ground magnesium limestone and basalt applications may improve chemical properties of Malaysian acid sulfate soils and rice growth. *Pedosphere*. 2014;24:827–835. doi: 10.1016/S1002-0160(14)60070-9.

Panique, E., Kelling, K.A., Schulte, E.E., Hero, D.E., Stevenson, W.R. and James, R.V (1997). Potassium Rate and Source Effects on Potato Yield, Quality, and Disease Interaction. *American Potato Journal*, 74(6):379-398.

- Prijambada, I. D. & E. Proklamasiningsih (2010). Effect of organic acids amendment on the growth and yield of soybean (*Glycine max*) in ultisol. *Int. J. Agric. Biol.*, 12: 566-570.
- Qian P., Sun R., Ali B., Gill R.A., Xu L., Zhou W (2014). Effects of hydrogen sulfide on growth, antioxidative capacity, and ultrastructural changes in oilseed rape seedlings under aluminum toxicity. *J. Plant Growth Regul.* 2014;33:526–538. doi: 10.1007/s00344-013-9402-0
- Raman H, Moroni JH, Saito K, Read BJ, Scott BJ (2002). Identification of AFLP and microsatellite markers linked with an aluminium tolerance gene in barley (*Hordeum vulgare* L.) *TheorAppl Genet.* 2002;105(2-3):458–464. doi:10.1007/s00122-002-0934-0
- Raman H, Wang JP, Read B, Zhou MX, Venkataganappa S, Moroni JS, O'Bree B, Mendham N (2005). Molecular mapping of resistance to aluminium toxicity in barley. *Proceedings of Plant and Animal Genome XIII Conference, San Diego, USA*, p. 154.
- Rashid, A., Khan, U.K. and Khan, D.J (2007). Comparative effect of varieties and fertilizer levels on barley (*Hordeum vulgare* L.). *Pakistan Journal of Soil Science*, 1: 1-13.
- Razaq M., Zhang P., Shen H. L (2017). Salahuddin Influence of nitrogen and phosphorous on the growth and root morphology of Acer mono. *PLoS ONE.* 2017;12:e0171321. doi: 10.1371/journal.pone.0171321.
- Read BJ, Oram RN (1995). *Hordeum vulgare* (Barley) cv. Brindabella. *Aust J Exp Agric.* 1995;35(3):425. doi: 10.1071/EA9950425
- Riaz M., Wu X., Yan L., Hussain S., Aziz O., Shah A., Jiang C (2018). Boron supply alleviates Al-induced inhibition of root elongation and physiological characteristics in rapeseed

- (*Brassica napus* L.) J. Plant Interact. 2018;13:270–276. doi: 10.1080/17429145.2018.1474391.
- Ripple, T, William L, Mary SPC, Michael W, Craig IC (2009). The effects of barely-derived soluble fiber on serum lipids. *Annals of Family Medicine*, 7(2): 157-163.
- Rut-Duga. D., Diriba. Shiferaw. G and Wogayehu. W (2019). Effects of Blended Fertilizer Rates on Bread Wheat (*TriticumAestivum* L.) Varieties on Growth and Yield Attributes
- Ryan, P. R., Raman, H., Gupta, S., Horst, W. J., and Delhaize, E (2009). A second mechanism for aluminum resistance in wheat relies on the constitutive efflux of citrate from roots. *Plant Physiol.* 149, 340–351.
- Saba Y., Alemu M. and Minale K (2009). (eds), presented at the Proceedings of the National Conference on Sustainable Land Management and Poverty Alleviation, Oromia Agricultural Research Institute 58 (ORARI) and College of Agriculture at Hawassa University, December, 2009 Addis Ababa, Ethiopia.
- Sahlemedhin S. and Taye B (2000). Procedures for Soil and Plant Analysis. National Soil Research Center Technical. Paper 74.NFIA, Addis Ababa, Ethiopia.
- Saifullah, Khan M.N., Iqbal M., Naeem A., Bibi S., Waraich E.A., Dahlawi S (2016). Elemental sulfur improves growth and phytoremediative ability of wheat grown in lead-contaminated calcareous soil. *Int. J. Phytoremediat.* 2016;18:1022–1028. doi: 10.1080/15226514.2016.1146226.
- Saisho, D. and Purugganan, M.D (2007). Molecular phylogeography of domesticated barley traces expansion of agriculture in the Old World. *Genetics.* 177: 1765-1776.

- Scott N.M. Sulphur in Soils and Plants. In: Vaughan D., Malcolm R.E (1985). editors. Soil Organic Matter and Biological Activity. Springer; Dordrecht, The Netherlands: 1985. pp. 379–401.
- Shahnaj, Y., Moushumi, A. and Belal, H (2014). Yield and Seed quality of barley (*Hordeum vulgare* L.) as affected by variety, nitrogen level and harvesting time. *International Journal of Agriculture and CropScience*. 7(5): 262-268.
- Shahryari, R. and V. Mollasadeghi. (2011). Correalation study of some traits affecting yield and yield components of wheat genotypes interms of normal irrigation and end drought stress. *Advances in Environmental Biology*. 5(3): 523-527.
- Shahzad, M.A., W.U., Din, S.T., Ehsanullah, and Ahmad M (2007). Effect of sowing dates and seed treatment on grain yield and quality of wheat. *Pakistan Journal of Agricultural Science*, 44(4): 581-583.
- Shorrocks M (2005).The occurrence and correction of boron deficiency. *Plant Soil*, 193:121–148.
- Shrivastava BK, MP Singh, SK Jain (1992). Effect of spacing and nitrogen levels on growth, yield and quality of seed crops of radish. *Seed Res.*, 20: 85–7.
- Silva I.R., Smyth T.J., Israel D.W., Raper C.D., Rufty T.W (2001). Magnesium ameliorates aluminum rhizotoxicity in soybean by increasing citric acid production and exudation by roots. *Plant Cell Physiol*. 2001;42:546–554. doi: 10.1093/pcp/pce067.
- Sinebo, W., Gretzmacher, R. and Edelbauer, A (2003). Environment of selection for grain yield in low fertilizer input barley. *Field Crops Research*. 74 (3-4): 151-162.

- Skwierawska M., Zawartka L., Zawadzki B (2008). The effect of different rates and forms of sulphur applied on changes of soil agrochemical properties. *Plant Soil Environ.* 2008;54:171–177. doi: 10.17221/391-PSE. soils. *Agronomy Journal*, 54:464–465.
- Slattery B, Hollier C (2002). The Impact of Acid Soils in Victoria. Report for the Department of Natural Resources and Environment, Goulburn Broken Catchment Management Authority, North East Catchment Management Authority. Department of Natural Resources and Environment, Rutherglen Research Institute.
- Suleiman A., Nganya J., and Ashraf M (2014). Effect of Cultivar and Sowing Date on Growth and Yield of Wheat (*Triticumaestivum* L.) in Khartoum, Sudan: *Journal of Forest Products & Industries*, 3(4): 198-203.
- Tahir M, Tanveer A, Shah TH, Fiaz N, Wasaya A (2009). Yield Response of Wheat (*Triticumaestivum* L.) to Boron Application at Different Growth Stages. *Pak. J. Life Soc. Sci.* 7:39-42.
- Tian, K.; Zhao, Y.; Xu, X.; Hai, N.; Huang, B.; Deng, W (2015): Effects of long-term fertilization and residue management on soil organic carbon changes in paddy soils of China: A meta-analysis. *Agric. Ecosyst. Environ.* 2015, 204, 40–50.
- Tan K., Keltjens W.G (1990). Interaction between aluminium and phosphorus in sorghum plants. *Plant Soil.* 1990;124:25–32. doi: 10.1007/BF00010927.
- Tandon, HLS (1995). Micronutrients in soil, crop and fertilizers. fertilizer development and consultation organization. New Delhi. 138 p.
- Tang Y, Sorrells ME, Kochian LV, Gravan DF (2000). Identification of RFLP markers linked to the barley aluminium tolerance gene *Alp* . *Crop Sci.* 2000; 40:778–782.

- Tang, Y., M.E. Sorrells, L.V. Kochian & D.F. Garvin (2000). Identification of RFLP markers linked to the barley aluminum tolerance gene *Alp*. *Crop Science* 40:778-782.
- Tariq A., Pan K., Olatunji O.A., Graciano C., Li Z., Sun F., Sun X., Song D., Chen W., Zhang A (2017). Phosphorous application improves drought tolerance of *Phoebe Zhennan*. *Front. Plant Sci.* 2017;8:1561. doi: 10.3389/fpls.2017.01561 tillage trial in Ethiopian highland vertisols:
- Tekalign Tadesse (1991). Soil, plant, fertilizer, animal manure and compost analysis manual. International Livestock centre for Africa, No. B13. Addis Ababa, Ethiopia.
- Teklay Tesfay and Girmay Gebresamuel (2016). Agronomic and economic evaluations of compound fertilizer applications under different planting methods and seed rates of tef [*Eragrostis tef* (Zucc.) Trotter] in Northern Ethiopia. *Journal of the Drylands*, 6(1): 409-422
- Tisdale, S. L., Nelson, W. J. and Beaton, J. D (1985). *Soil Fertility and Fertilizers*. 4th ed. USA. 284p.
- USDA (United States Department of Agriculture). (2017). *World Agricultural Production U.S.* Department of Agriculture Foreign Agricultural Service / Office of Global Analysis International Production Assessment Division (IPAD) Ag Box 1051, Room 4630, South Building Washington, DC 20250-1051
- Vance C.P., Uhde-Stone C., Allan D.L (2003). Phosphorus acquisition and use: Critical adaptations by plants for securing a nonrenewable resource. *New Phytol.* 2003;157:423–447. doi: 10.1046/j.1469-8137.2003.00695.

- Voltas, J., Romagosa, I., Lafarga, A., Armesto, A.P., Sombrero, A. and Araus, J.L (1998). Genotype by environment interaction for grain yield and carbon isotope discrimination of barley in Mediterranean Spain. *Australian Journal of Agricultural Research*. 50: 1263–1271.
- Wakene T., Walelign W. and Wassie H (2014). Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley (*Hordeum vulgare* L.) at Bore District, Southern Oromia, Ethiopia. *American Journal of Life Sciences* 2(5): 260-266
- Walkley, A. and Black, I. A (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37: 29-37.
- Walkley, A. and Black, I.A (1934). An examination of the digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method *Soil Science*, 37: 29-38.
- Wang J, Raman H, Zhou M, Ryan P, Delhaize E, Hebb D, Coombes N, Mendham N (2007). High-resolution mapping of the *Alp* locus and identification of a candidate gene *HvMATE* controlling aluminium tolerance in barley (*Hordeum vulgare* L.). *Theor. Appl. Genet.*, 115:265-276.
- Wang JP, Raman H, Read B, Zhou MX, Mendham NJ, Venkatanagappa S (2006). Validation of an Alt locus for aluminium tolerance scored with eriochrome cyanine R staining method in barley cultivar Honen (*Hordeum vulgare* L.) *Aust J Agric Res*. 2006;57(1):113–118. doi: 10.1071/AR05202.

- Wang X., Yan X., Liao H (2010). Genetic improvement for phosphorus efficiency in soybean: A radical approach. *Ann. Bot.* 2010;106:215–222. doi: 10.1093/aob/mcq029.
- Wang, J.P., Raman H., Zhang G.P., Mendham N. and Zhou M.X (2006). Aluminium tolerance in barley (*Hordeum vulgare* L.): physiological mechanisms, genetics and screening methods. *Journal of Zhejiang University Science.* 7:769-787.
- Wassie H and Shiferaw B (2009). Mitigation of soil acidity and fertility decline challenges for sustainable livelihood improvement: Evidence from Southern region of Ethiopia. In: Atlaw
- Wassie H and Shiferaw B (2011). Response of Irish potato (*Solanum Tuberosum* L.) to the application of potassium at acidic soils of Chenchu, Southern Ethiopia. *Int. J. Agric. Biol.* 13: 595–598
- Worku, M., Friesen, B.E., Diallob, O.A. and Horst, W.J (2007). Nitrogen uptake and utilization in contrasting nitrogen efficient tropical maize hybrids. *Crop Science.* 47: 519-528.
- Wosene Abtew and Berhane Lakew (2015). Ethiopian barley landraces show higher yield stability and comparable yield to improved varieties in multi environment field trials. *Journals of Plant Breeding and Crop Science*, 7(8): 1-17.
- Xu AB, Dang BY, Zhu MY, Yuan MB, Huang CN, Yu JJ, Huang Q, Wu YL, Ni ZY (1991). Screening barley varieties for tolerance of acidic aluminium. *Crop genet Res.* 1991;3:1719
- Yamaji, N., Huang, C. F., Nagao, S., Yano, M., Sato, Y., Nagamura, Y (2009). A zinc finger transcription factor ART1 regulates multiple genes implicated in aluminum tolerance in rice. *Plant Cell* 21, 3339–3349

- Yang S, Wei Y, Qi P, Zheng Y (2008). Sequence polymorphisms and phylogenetic relationships of hina gene in wild barley from Tibet, China. *Agricultural Sciences in China* 7(7): 796-803.
- Yu M., Shen R., Xiao H., Xu M., Wang H., Wang H., Zeng Q., Bian J. Boron alleviates aluminum toxicity in pea (*Pisumsativum*) Plant Soil. 2009;314:87. doi: 10.1007/s11104-008-9708-z
- Zafar M, Abbasi MK, Khaliq A (2013). Effect of different phosphorus sources on the growth, yield, energy content and phosphorus utilization efficiency in maize at Rawalako Azad Jammu and Kashmir, Pakistan. *Journal of Plant Nutrition* 36:1915-1934.
- ZemedAsfaw (1996). Barley in Ethiopia: the link between botany and tradition. pp 182– 192, in: HailuGebre and J.A.G. van Leur (eds.). *Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of the 1st Barley Research Review Workshop*, 16–19 October 1993, Addis Ababa. IAR/ICARDA, Addis Ababa, Ethiopia.66
- ZemedASfaw (2000). The Barleys of Ethiopia. In: Stephen B (ed.) *Genes in the Field: On-farm Conservation of Crop Diversity*. IDRC, Ottawa, Canada, pp: 77-107
- Zhang H., Tan Z.-Q., Hu L.-Y., Wang S.-H., Luo J.-P., Jones R.L (2010). Hydrogen sulfide alleviates aluminum toxicity in germinating wheat seedlings. *J. Integr. Plant Biol.* 2010;52:556–567. doi: 10.1111/j.1744-7909.2010.00946.
- Zhang J., Zhao C.-Y., Liu J., Song R., Du Y.-X., Li J.-Z., Sun H.-Z., Duan G.-L., Zhao Q.-Z (2016). Influence of sulfur on transcription of genes involved in arsenic accumulation in rice grains. *Plant Mol. Biol. Rep.* 2016;34:556–565. doi: 10.1007/s11105-015-0937-z.

- Zheng S.J., Yang J.L., He Y.F., Yu X.H., Zhang L., You J.F., Shen R.F., Matsumoto H (2005). Immobilization of aluminum with phosphorus in roots is associated with high aluminum resistance in buckwheat. *Plant Physiol.* 2005;138:297–303. doi: 10.1104/pp.105.059667.
- Zhou, G. F., Delhaize, E., Zhou, M. X., and Ryan, P. R (2013). The barley MATE gene, HvAACT1, increases citrate efflux and Al³⁺ tolerance when expressed in wheat and barley. *Ann. Bot. Lond.* 112, 603–612.
- Ziaeyan, M. Rajaiea, *J. Plant Production* ., 2009, 3, 3, 1735.
- Zorb, C., Senbayram, M. and Peiter, E (2014). Potassium in agriculture-status and perspectives. *Better Crops with Plant Food*, 98(2), pp.29-31.
- Zoz, F. Steiner Rubens Fey, *J. Ciência Rural, Santa Maria*, 2012, 42, 5,784.

7. APPENDICES

7.1. Tables in Appendices

Table1: Mean square values date of emergency, date of heading and date of maturity.

Source of variation	DF	DE(days)	DH(days)	DM(days)
Block	2	0.26 NS	0.80 NS	9.51NS
Genotypes	4	14.26***	2443.77**	3927.9***
Types of Fertilizers	3	0.00NS	123.79***	328.11***
Genotype X Fertilizers	11	0.0NS	0.64NS	28.83***
Error	39	0.056	2.449	4.86
CV		2.98	2.127	2.306

*, ** &***, ns indicate significant, highly significant and non significant variations respectively.

Table2: Mean square values of plant height, number of effective tiller, Spike length and Number of grain per spike.

Source of Variation	Degree Freedom	Number of grain per spike	Number of effective tillers (m ²)	Spike length (cm)	Number of grain per spike
Block	2	37.78 NS	23.21 NS	2.18 NS	9.57NS
Genotypes	4	1757.96***	2439.04***	40.52***	2887.17***
Types of Fertilizers	3	1772.95***	1169.17***	29.71***	743.57***
Genotype X Fertilizers	11	88.44**	103.83***	0.89NS	14.89NS
Error	39	23.78	17.79	4.86	9.94
CV		.5.69	9.55	11.26	8.65

*, ** &***, ns indicate significant, highly significant and non significant variations respectively

Table 3: Mean square values of above ground total biomass, grain yield and Straw yield.

Source of Variation	Degree Freedom	Above ground total biomass (ton ha ⁻¹)	Grain yield (ton ha ⁻¹)	Straw yield (ton ha ⁻¹)
Block	2	1.61 NS	0.126 NS	2.32 NS
Genotypes	4	35.96***	7.52***	11.31***
Types of Fertilizers	3	82.61***	17.92***	23.79***
Genotype X Fertilizers	11	1.70**	0.40***	0.51NS
Error	39	0.59	0.058	0.57
CV		.9.58	8.25	14.71

*, ** &***, ns indicate significant, highly significant and non significant variations respectively.

Table4: Mean square values of 1000s grain weight and Harvest index.

Source of Variation	Degree Freedom	1000s grain weight (g)	Harvest index (%)
Block	2	5.16 NS	73.26NS
Genotypes	4	221.01***	91.13***
Types of Fertilizers	3	908.44***	281.64***
Genotype X Fertilizers	11	8.00NS	3.79NS
Error	39	3.96	16.11
CV		.6.11	11.40

*, ** &***, ns indicate significant, highly significant and non significant variations respectively.

Table 5: Soil pH rating for 1: 2.5 soils to water ratio suspension

PH	Ratings
>4.5	Very strongly acidic
4.5-5.2	Strongly acidic
5.3-5.9	Moderately acidic
6.0-6.6	Slightly acidic
6.7-7.3	Neutral
7.4-8.0	Moderately alkaline
> 8.0	Strongly alkaline

Source: Tekalgn (1991).

Table 6: Mean monthly and annual maximum temperature (⁰C) at Hagerselam hula woreda (2010-2019)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	19.2	19.4	19.6	20.5	20.7	20.5	15.8	16.0	18.2	19.7	19.6	20.2
2011	20.0	20.0	19.7	19.7	18.9	18.6	18.5	17.1	18.6	20.8	20.7	NA
2012	24.5	24.5	24.2	18.4	18.6	18.2	NA	17.1	17.8	18.9	20.0	24.1
2013	26.0	25.8	NA	19.3	19.1	18.8	NA	NA	NA	NA	23.9	27.2
2014	NA	NA	NA	NA	NA	22.5	21.8	19.2	19.6	19.8	21.6	23.4
2015	27.3	25.4	24.0	19.7	18.9	19.1	18.6	18.6	19.7	19.8	20.1	20.6
2016	21.6	20.5	22.6	19.8	18.6	18.0	18.6	19.0	19.4	19.7	22.5	25.6
2017	27.3	26.1	26.3	23.6	NA	NA	17.7	17.7	18.6	19.8	21.3	25.5
2018	26.4	23.7	19.7	19.3	20.1	21.2	20.3	21.1	NA	NA	NA	NA
2019	NA	NA	NA	NA	NA	NA	19.3	20.0	20.1	22.2	21.6	24.5

Source: (NMSA, 2019)

Table7: Mean monthly and annual minimum temperature (⁰C) at Hagerselam Hula woreda (2010-2019).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	6.0	6.7	7.2	8.2	9.1	8.0	7.2	7.4	7.3	7.0	5.9	5.1
2011	6.0	6.2	6.7	7.1	7.6	7.3	6.2	6.5	7.3	5.9	6.1	0.0
2012	5.2	5.5	6.9	5.4	5.6	5.5	0.0	6.1	6.0	5.6	5.7	4.6
2013	5.2	5.1	NA	5.6	5.6	5.5	NA	NA	NA	NA	5.8	3.4
2014	NA	NA	NA	NA	NA	6.1	5.1	3.8	4.9	6.0	6.4	4.5
2015	6.5	6.3	5.3	4.6	4.7	5.0	3.8	4.2	4.1	4.4	4.7	4.7
2016	5.0	5.4	5.6	5.3	4.7	3.7	3.5	3.4	4.2	4.1	3.3	3.1
2017	2.7	4.2	4.2	3.9	NA	NA	3.0	2.8	3.2	3.9	3.8	3.4
2018	4.7	3.7	3.3	2.7	3.4	4.9	3.8	3.8	NA	NA	NA	NA
2019	NA	NA	NA	NA	NA	NA	4.9	4.5	4.7	4.6	4.4	4.2

Source: (NMSA, 2019)

Table 8: Monthly and yearly total rainfall (mm) at Hagerselam Hula woreda (2010-2019).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	25.9	181.6	200.7	263.1	329.9	111.1	96.3	130.6	193.2	214.5	3.6	6.1
2011	18.1	35.7	51.3	48.4	368.4	150.2	143.3	154.5	150.2	199.4	259.7	NA
2012	2.4	2.1	24.5	264.7	137.2	112.2	89.1	78.8	158.9	145.1	39.2	34.5
2013	5.9	NA	NA	322.4	328.4	116.9	NA	NA	NA	NA	119.2	0.0
2014	38.1	77.3	NA	35.4	224.4	262.3	137.7	239.3	245.2	205.4	110.6	18.2
2015	30.0	22.6	35.7	244.1	244.9	113.8	58.5	135.8	122.1	116.4	152.4	74.2
2016	29.5	10.5	75.3	199.8	283.0	179.6	133.5	182.2	159.6	176.8	47.8	0.0
2017	1.0	5.2	50.4	71.6	NA	NA	218.8	206.0	365.1	342.1	34.5	16.1
2018	4.6	109.9	137.7	476.7	172.4	118.6	106.0	112.2	167.3	185.8	112.8	34.9
2019	NA	NA	NA	NA	NA	NA	364.4	160.1	161.7	100.7	179.3	60.0

Source: (NMSA, 2019)

7.2: Figures in Appendices



Figure 1: Land Preparation



Figure 2: Day of Sowing



Figure3: Day of Weeding



Figure4: Day of urea Application



Figure5: Field supervision



Figure 6: Data collection



Figure7: Day of harvesting

BIOGRAPHICAL SKETCH

The author was born from his father Mr. Hameso Bora and his mother Mrs. Dusharu Duge in Bansa Woreda, Sidama Zone of SNNPRS, on the 10th of June 1993. He attended elementary and primary, secondary and preparatory education at Alo Primary School, Kebena Gata Secondary and Preparatory School, respectively. After passing the Ethiopian General Secondary Education Certificate Examination (EGSECE), he joined woldia University in 2015 and graduated with the Degree of Bachelor of Science in Plant Sciences in July 2017.

In October 2018, he was employed by Bensa woreda Agricultural bureau as expert of crop production and he served up to September 2019. In October 2019, he joined the School of Graduate Studies, Hawassa University to pursue his study leading to the Degree of Master of Science in Agronomy.