ORIGINAL ARTICLE

Effect of inorganic fertilizer types on yield performance of barley (*Hordeum Vulgare L.*) genotypes and soil characteristics under acidic soil conditions

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ABSTRACT

Barley (*Hordeum vulgare L.)* is one of the most important cereal crops in the world and staple food grain, for Ethiopian highlanders. However, the barley productivity is commonly influenced by different biotic and abiotic factors. Soil acidity is one of environmental factors affecting growth and crop yield. Field experiment was conducted under acidic soil of Hagereselam, southern Ethiopia in 2019 cropping season to evaluate yield performance of barley genotypes and soil characteristics 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 or only urea, NP, NPS and NPSB) and four barley genotypes (217176b, 240478, 234911b and 208855b) and one barley variety (HB- 1307). Barley Genotype 217176b with NPSB fertilizer exhibited the highest grain yield of 4.9 ton ha^{-1}. This 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}). Genotypes 217176b and 240478 were categorized as efficient in nutrient use and responsive to fertilization under the evaluation. The highest marginal rate of return (3745) was recorded for genotype 217176b with the application of the recommended rate of NPSB fertilizer. Greater net benefit with above the threshold marginal rate of return (100%) was also obtained for the same genotype with NP fertilization. Similarly economically acceptable marginal rate of return 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.

Keywords: Grain Yield, Grain yield response index, Interaction effect, Soil Acidity

INTRODUCTION

Barley is one of the most important cereal crops in the world, ranking fourth in production area next to wheat, maize and rice (USDA, 2017). It ranks the fifth important crop after maize, *teff*, sorghum and wheat in Ethiopia (CSA, 2018). The national average yield of barley in Ethiopia is low (2.2 ton ha^{-1}) (CSA, 2018) due to several contributing including environmental and socioeconomic constraints (Mulatu and Grando, 2011). Declining soil fertility is one of the major challenges to barley production and productivity in Ethiopia (Amsal and Tanner, 2001). Soil acidity is one of the major constraints affecting crop productivity covering about 43% of the cultivated land in humid and sub-humid highlands of Ethiopia (Agegnehu *et al.,* 2017). Moreover, Soil acidity is one of 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 is considerable evidence in literature that showed that soil pH < 5.5 affects the growth of crops due to high concentration of aluminum and manganese, and deficiency of P, N, S and other nutrients nutrients (Gebremedhn and Berhanu, 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 severe yield losses and deteriorated nutritional quality of the crops. In acidic soils, most of agricultural crops show poor performance even with the application of lime (Yasufumi, 2013).

Barley is 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/Al^{3+}. 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). This may be responsible for the constantly low barley yields despite the release of high yield potential varieties. 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). It is important to identify genetic resources with a potential for tolerance to these different stresses, in order to breed tolerant barley cultivars (Pickering *et al*., 2005). Barley genotypes offer a great source of useful genes and genetic variation for crop improvement. Therefore, low-cost, effective and environmentally friendly approaches are in high demand. In this regard, the application of adequate mineral nutrition and use of efficient varieties would be a suitable strategy for minimizing soil acidity related yield reduction. Farmers in the study area face severe yield reduction due to soil acidity. Therefore, this experiment was conducted to examine the response of barley genotypes to inorganic fertilizer types and to evaluate and identify inorganic fertilizer types that are effective under acidic soil conditions at Hagerselam.

MATERIALS AND METHODS

Description of Study Site

This study was conducted at Hagerselam, southern Ethiopia during the main cropping seasons of 2019. Hagerselam is located at 38^0 27′44′′E longitude and 06^0 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 soil classification system the dominant soil type of the study site is Nitiosls, with textural class of clay loam.

Treatments and experimental design

Experimental sites selection was carried out from April to June 2019. Then, the land preparation and field leveling was done by manually. The soil samples were collected in diagonal soil sampling method from each field and made one composite sample per field before planting. Factorial experiment consisting of four fertilizer types (control or only N, NP, NPS, NPSB), and four barley genotypes from Ethiopian Biodiversity institute (217176b, 240478 and 234911b 208855b) and one variety (HB-1307) were used as experimental materials (Table 1). A Total of 20 treatments combination was laid out in RCBD with three replications. The spacing between plots and block was 0.5 m and 1 m, respectively. The plot size was 1.6 x 1.5 m (2.4 m^2) accommodating eight rows of barley plants. Seed was sown at a spacing of 20 cm between rows. The recommended rates of NPS at 100 kg ha^{-1}, NPSB at 100 kg ha^{-1}, and NP at100 kg ha^{-1} were applied as per treatments with basal dressing at the time of sowing barley. The recommended rate of urea (100 kg ha^{-1}) was uniformly applied to all plots in split application at planting and after planting.

Table 1: Description of genotypes used in the study

Genotypes	Collected area	
	Region	District
217176b	Southern Ethiopia	Decha
240478	Southern Ethiopia	Chena
234911b	Southern Ethiopia	Masha Anderacha
208855b	Sidama region	Hagereselam
HB-1307 (variety)	Released by Holetta Agricultural Research Center at 206	

Soil sample preparation and laboratory 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).

Data Collection and Analyses

- **Grain yield:** Grain yield was measured after harvesting the crop from the net plot area of 1.8 m^2 containing six harvestable rows.
- **Above ground biomass yield:** Biomass yield was measured by weighing the sun dried total above ground plant biomass (straw + grain) of the net plot.
- **Straw yield:** Straw yield was measured by subtracting the grain yield from the total above ground biomass yield after threshing.
- **Harvest index:** Harvest index was calculated by dividing grain yield by the total above ground air dry biomass yield.
- **Grain yield response index:** Grain yield response index (GYRI) was calculated for each genotype according to the concept of Fageria and barbosa filho (1981) by selecting the fertilizer that caused the highest response, using the following equation:

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

Types of fertilizers	N (kg ha -1)	P_2O_5 (kg ha -1)	S (kg ha-1)	B (kg ha -1)
Urea	46	18	0	0
NP	64	46	-	-
NPS	65	38	7	-
NPSB	64.9	37.7	6.95	0.1

$$\text{GYRI} = \frac{\text{Grain yield under fertilizer} - \text{Grain yield under control}}{\text{Content of nutrient in fertilizer} - \text{nutirient content of Control fertilizer}}$$

Partial budget analysis

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.

Data Analysis

Data were subjected to analysis of variance (ANOVA) using SAS software version 9.0 (SAS, 2004). For parameters whose ANOVA was tested significant with respect to treatment effects, further means separation was done using least significant difference (LSD) method at 0.05 probability levels.

RESULTS AND DISCUSSIONS

Soil physico-chemical pproperties 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 pH of the soil was 4.48 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. The OC concentration of the study site was 2.38%. 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 EthioSIS (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 sit was 4.21 mg kg^{-1}. 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. Habtamu, *et al*. (2015) reported that under acidic soil low content of P was due to fixation problem. The CEC of the site was 19.78cmol kg^{-1}. 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}. According to EthioSIS (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.

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 3). 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 NH_4 rather than No^-_3 because microorganism activity is slow in acidic soil to change NH_4 to No^-_3. 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 NH_4. 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) $mgkg_{-}^{-1}$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).

Above Ground Biomass

The analysis of variance showed that biomass yield of barley was significantly influenced ($P < 0.05$) due to interaction effects of genotypes and the different types of inorganic fertilizers (Figure 1). Significantly higher biomass yields were obtained from genotypes 217176b and 240478 with application of NPSB and NP fertilizers without statistical difference between them (Figure 1). Lower biomass yields were recorded for all genotypes under the control fertilization.

An increase in biomass yield might result from the overall improvement of vegetative growth of the plant due to the blended application of inorganic fertilizers. Additionally, the increase in biological yield of barley from plots fertilized with NPSB and NP might be the result of proper and balanced supply of nutrients to the plants throughout the growth period and solubility potential of NPSB and due to increased amount of P in NP fertilizer which elevate aluminum from soil solution. 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 a blended fertilizer. The report by Shiferaw (2012) also indicated that above ground dry biomass yield was significantly affected by application of blended fertilizer and NP

Table 3: Effect of different types of Inorganic Fertilizers and Barley Genotypes Combinations on Soil Chemical Properties under Acidic Soil, After Harvesting

Genotypes	Fertilizers	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
	Mean ± SE	4.53±0.06	23.22±0.33	0.14±0.00	4.46±0.40	0.45±0.22	0.67±0.08	2.11±0.28
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
	Mean ± SE	4.52±0.06	23.42±0.33	0.14±0.00	4.35±0.38	0.46±0.03	0.67±0.09	2.12±0.28
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
	Mean ± SE	4.53±0.07	23.44±0.33	0.14±0.00	4.47±0.41	0.45±0.03	0.68±0.09	2.12±0.29
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
	Mean ± SE	4.52±0.07	23.41±0.33	0.14±0.00	4.47±0.41	0.47±0.0411	0.66±0.10	2.13±0.30
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
	Mean ± SE	4.55±0.06	23.43±0.34	0.14±0.00	4.34±0.37	0.48±0.04	0.55±0.20	2.12±0.28

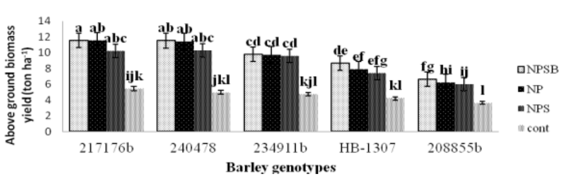

Figure 1: Interaction effects of barely genotypes and inorganic fertilizer types with regard to above ground biomass yield (ton ha^{-1}).

Grain Yield

The analysis of variance revealed significant (P ≤ 0.001) difference due to interaction effects of genotypes and types of inorganic fertilizers on grain yield (Figure 2). Genotype 217176b with NPSB fertilizer exhibited the highest grain yield (4.9 ton ha^{-1}) but had no significant difference with yield obtained under NP fertilizer with same genotype (4.72 ton ha^{-1}) and to that of genotype 240487 with NPSB fertilizer (4.58 ton ha^{-1}). In this regard, the addition of P alleviates Al toxicity by increasing root growth and nutrient uptake that lead to enhanced grain yield. This confirms the findings of Rut *et al*. (2019) who recorded similar yields from application of recommended NP and NPSB on wheat varieties. 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. Moeinian *et al*. (2011) indicated that boron application has a key role in plant metabolism and in enhancing root growth through better use of nitrogen and synthesis of more carbohydrates and proteins. Feyera *et al*. (2014) reported that the agronomic performance is improved through application of a blend of macro and micronutrient in nutrient deficient soil, which improved nutrient use efficiency, increased the grain productivity of *teff*. In this experiment, presence of boron in NPSB formulation did not lead to a significantly different improvement in grain yield compared to NP alone.

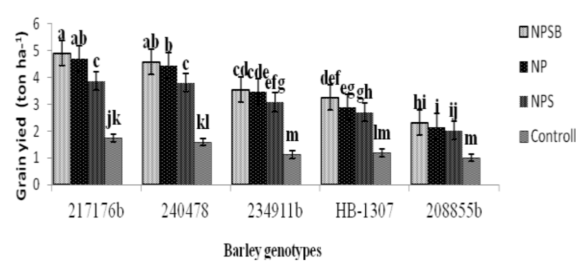

Figure 2: Interaction effects of barely genotypes and inorganic fertilizer application on grain yield.

Straw Yield

The analysis of variance showed that straw yield of barley was significantly influenced (P ≤0.001), due to main effects of genotypes and different types of inorganic fertilizers but not by the interaction effect (Table 4). Significantly higher straw yields were obtained from genotypes 240478, 217176b and 234911b without statistical difference among them. Whereas, the lowest straw yield (3.73 ton ha^{-1}) was recorded from genotype 208855. All fertilizer types gave significantly greater straw yields compared to the control fertilizer and there were no statistical differences among the effects of NP, NPS and NPSB. It suggests that presence of N and P seems to influence straw yield primarily irrespective of the involvement of micronutrients. Regarding the role of N, Amsal *et al.* (2000) reported that N significantly enhanced the straw yield of wheat, since N usually promotes the vegetative growth of a plant.

Harvest Index

Analysis of variance indicated that the harvest index was significantly ($p < 0.01$) affected by genotypes and inorganic fertilizers (Table 4). Harvest index is the ratio of grain yield to the aboveground biomass yield expressed as coefficient of effectiveness. Genotypes 217176b and 240487 produced greater harvest indices. There was variation in harvest index among the different barley genotypes due to their inherent genetic 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 39% and 38% were obtained from applications of NPSB and NP fertilizer, respectively. The lowest HI (28.10%) was obtained from the control fertilizer indicating the contribution of P in raising harvest index. Riggs *et al.* (1981) reported a high and significant positive relation between harvest index and grain yield in barley.

Table 4: Effect of Barley Genotypes and Types of Inorganic Fertilizers on Straw Yield and Harvest Index under Acidic Soil of Hagereselam, Southern Ethiopia

Fertilizers	Straw yield ton ha^{-1}	Harvest index (%)
NPSB	5.908a	38.593^{a}
NP	5.81^{a}	37.69^{ab}
NPS	5.60^{a}	35.487^{b}
Control	3.27^{b}	28.993^{c}
Fertilizer	***	***
LSD	0.56	2.96
Genotypes		
217176b	5.88^{a}	38.63^{a}
240478	5.93^{a}	37.38^{ab}
234911b	5.65^{a}	32.025^{c}
208855b	3.73^{c}	33.208^{c}
HB- 1307	4.54^{b}	34.76^{bc}
Genotype	***	***
LSD	0.62	3.32
Fertilizer X genotypes	NS	NS
CV	**14.71**	**11.42**

Grain Yield Response Index (GYRI)

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 fertilizers and their response to NPSB fertilizer. Barley genotype 217176b and 240478 belonged to efficient and responsive (ER) group, which exceeded the averages of grain yield at control fertilizer application and the mean GYRI value. Genotypes 234911b was under non efficient and responsive (NER) group being with lower grain yield at control fertilizer and higher GYRI than the average. Barley genotypes 208855b and variety HB-1307 were non efficient and non-responsive (NENR), whereby both grain yield at control fertilizer and mean GYRI were lower. According to the GYRI parameter, results indicated considerable differences among the barley genotypes for absorbing and utilizing nutrients from deficient soils. GYRI values were larger compared to previously reported ones probably due to absence of zero fertilizer level in our study. 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 a source of desirable genes to incorporate the adaptation for low nutrient availability and high utilization efficiency of applied nutrients. 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 are largely due to variation in utilization of accumulated nutrient, but with high nutrient, they were largely due to variation in uptake efficiency (Noureldin *et al.*, 2013). 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 (Noureldin *et al.*, 2013).

Economic Analysis

The highest net benefit (ETB 59932 ha $^{-1}$) and marginal rate return (MRR) (3745%) with value to cost ratio of ETB 10.32 per unit of investment were obtained from combination of genotype 217176b with NPSB fertilizer (Table 5). This was followed by net benefit of ETB 55700 a^{-1} and marginal rate of return of 3664 % 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 ETB 1.00 invested for NPSB fertilizer, producers can expect to recover ETB 1.00 and obtain an additional of ETB 37.45 and 36.64 for barley genotypes 217176 b and 240478, , respectively. Similarly, 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 genotypes 217176b and 240478 with either NPSB or NP were economically feasible for barley production under Acidic soil of Hagerselam.

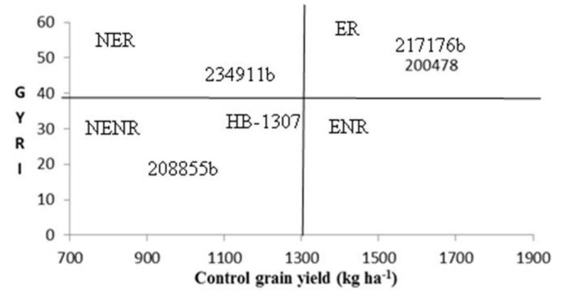

Figure 3: Grain Yield Response Index (GYRI) of tested barley genotypes. ER, efficient and responsive; NER, not efficient and responsive; ENR, efficient and not responsive; NENR, not efficient and not responsive

Table 5: Partial Budget Analysis of Barley Genotypes Yield as Influenced By Types of Inorganic Fertilizer Application

Inorganic Fertilizer Types	Barley Genotypes	Adjusted grain yield (ton ha^{-1})	Gross field benefits (Birrha^{-1})	Total variable cost (Birr ha^{-1})	Net benefits (Birr ha^{-1})	Marginal Rate of Return%
Control	208855b	0.909	12953	1338	11615	-
	HB-1307	1.08	15390	1541	14052	1200.9
	234911b	1.017	14492	1545	13154.	D
	240478	1.431	20391	1767	19053	2657.4
	217176b	1.566	22315	1889	20977	1576.8
NPS	208855b	1.827	26034	2568	23466	366.6
	HB-1307	2.439	34755	2875	32187	2840.7
	234911b	2.772	39501	3089	36933	2217.4
	240478	3.42	48735	3396	46167	3007.8
	217176b	3.843	54762	3587	52194	3155.8
NP	208855b	1.953	27830	3592	25000	D
	HB-1307	2.601	37064	3895	34234	3047.5
	234911b	3.123	44502	4163	41672	2775.5
	240478	4.005	52071	4394	49241	3276.4
	217176b	4.248	60534	4645	55889	3371.6
NPSB	208855b	2.097	29882	4652	26844	D
	HB-1307	2.925	41681	5127	38643	2484.0
	234911b	3.204	45657	5339	42619	1875.3
	240478	4.122	58738	5696	55700	3664.2
	217176b	4.419	62970.	5809	57161	3745.3

CONCLUSION

Application of adequate mineral nutrition and use of acid tolerant varieties would be a suitable strategy for minimizing soil acidity related yield reduction. Genotype 217176b gave higher grain yields either with NPSB or NP fertilizer application. Similarly, genotype 240478 with NPSB fertilizer gave greater grain yield. Better straw yields were obtained from genotypes 240478, 217176b and 234911b and all fertilizer types gave significantly greater straw yields, as compared to the control. Barley genotypes 217176b and 240478 belonged to the efficient and responsive category indicating that these two genotypes were efficient in utilizing soil nutrients and were also responsive to additional fertilizer applications. Furthermore, greater marginal rate of return (MRR %) values well above the 100% threshold value were recorded from genotypes 217176b and 240478 either with NPSB or NP fertilizer application 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.

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REFERENCES

Achalu, C, Heluf, G., Kibebew, K, and Abi T. 2012. Response of barley to liming of acid soils collected from different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Science* 2(7):1-13.

Agegnehu, G and Amede, T. 2017. Integrated soil fertility and plant nutrient management in tropical agro-ecosystems: A review. Pedosphere 27, 662-680.

Amsal, T and Tanner, D. 2000. 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.

Asefa, F., Debela, A and Mohammed, M. 2014. Evaluation of Tef [*Eragrostistef* (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

Brady, NC and Weil, RR. 2002. The nature and properties of soils thirteenth edition Prentice Hall, New Jersey.

Bray, RH and Kurz, LT. 1995. Determination of total, organic and available forms of phosphorous in *soil*. *Soil Sci* 59(1): 39-45.

Chen, RF, Zhang, FL, Zhang, QM, Sun, QB, Dong, XYand Shen RF. 2012. Aluminium-phosphorus interactions in plants growing on acid soils: Does phosphorus always alleviate Aluminium toxicity? *Journal of Science Food and Agricculture* 2012;92:995–1000.

Chen, ZC and Liao H. 2016. Organic acid anions: An effective defensive weapon for plants against aluminum toxicity and phosphorus deficiency in acidic soils. *Journal of Genetics and Genomics* 43:631-638.

CSA 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.

EthioSIS 2013.Towards improved fertilizer recommendations in Ethiopia-Nutrient indices for categorization of fertilizer blends from EthioSISworeda soil inventory data. Addis Ababa, Ethiopia.

EthioSIS 2014. Soil Fertility and fertilizer recommendation Atlas of Tigray Region. Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA).

Fageria, N K. and Nascente, AS. 2014. Management of soil acidity of South American soils for sustainable crop production. *Adv. Agron*. 128, 221-275.

Fayera, A, Adugna, D and Muktar M. 2014. Evaluation of Tef [Eragrostistef (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

Gebremedhn, Y, and Berhanu, A. 2013.The role of seed priming in improving seed germination and seedling growth of maize (*Zea mays* L.) under salt stress at laboratory conditions: *Africa journal of biotechnology*.vol.12.No.46: 6484-6490

Getachew, A, Chilot, Y and Teklu, E. 2019. Soil Acidity Management. Ethiopian Institute of Agricultural Research (EIAR). Addis Ababa, Ethiopia.

Gong, W, Yan, X, Wang, J, Hu, T and 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.

Habtamu, A, Heluf G, Bobe B and Enyew, A. 2015. 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.

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

Havlin, JL, Beaton, JD, Tisdale, SL and Nelson, WL. 1999. *Soil fertility and fertilizer:an introduction to nutrient management* Prentice Hall, New York, 499p.

Ladha, JK., Kesava Reddy, C, Padre, AT and 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.256.

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.

Martin, JH, Walden, RP and Stamp DL. 2006. Principle of field crop production. Pearson Education, Inc. Upper Saddle River.

Menz, J, LiZ, Schulze WX and Ludewig, U. 2016. Early nitrogen deprivation responses in Arabidopsis roots reveal distinct differences on transcriptome and (phospho) proteome levels between nitrate and ammonium nutrition. *The Plant Journal* 88:717-734.

Mesfin, A. 2007. Nature and management of acid soils in Ethiopia. Addis Ababa, Ethiopia. P 99.

Moeinian, MR., Zargari, K and Hasanpour, J. 2011. Effect of boron foliar spraying application on quality characteristics and growth parameters of wheat grain under drought stress. Amer. Eur. J. Agric. Environ. Sci, 10: 593-599.

Mohammed, YA., Kelly, J, Chim BK., Rutto E and Waldschmidt K. 2011. Nitrogen Fertilizer Management for Improved Grain Quality and Yield in Winter Wheat in Oklahoma. *Journal of Plant Nutrition* 36(5)

Mulatu, B. and Grando, S. (eds). 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.

Noureldin, NA., Saudy HS., Ashmawy F and Saed, HM. 2013. Grain yield response index of bread whea cultivars as influenced by nitrogen levels. *Annals of Agricultural Science* 58:147-152.

Olsen, S, Cole, C., Watanabe, F and 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.

Pickering, R, Johnston, PA. 2005. Recent progress in barley improvement using wild species of *Hordeum*. *Cytogenet. Genome Res.* **2005**, *109*, 344–349.

Riggs, TJ, RP, Hanson, ND, Start, OM, Miles, cL, Morgan, and MA Ford. 1981. Comparison of spring barley varieties grown in England and Wales between 1880 and 1980. Joumal of Agricultural Science, Cambridge 97:599-610.

Rut-Duga, D. 2019. Effects of Blended Fertilizer Rates on Bread Wheat (Triticum Aestivum L.) Varieties on Growth and Yield Attributes. *Biology Agriculture and Health Care* 9:15

Shahryari and Mollasadeghi 2011. Correlation, Path Analysis and Stepwise Regression in Durum Wheat (Triticum Durum Desf.) under Rainfed Conditions: Journal of Agriculture and Sustainability: Volume 3, Number 2, 2013, 122-13

Shiferaw, A. 2012. Strengthening Informal Seed Multiplication -Community Seed Banks in Alaba Special Wereda, pp. 293-305, published by *Ethiopian Institute of Agricultural Research* (EIAR), Addis Ababa, Ethiopia,

Tekalign, T. 1991. Soil, Plant, Water, Fertilizer, Animal Manure and Compost Analysis. Working Document No. 13, International Livestock Research Center for Africa, Addis Ababa. International Livestock centre for Africa, No. B13. Addis Ababa, Ethiopia.

Tian, K., Zhao, Y, Xu, X, Hai, N, Huang, B and Deng, W. 2015. Effects of long-term fertilization and residue management on soil organic carbon changes in paddy soils of China: A meta-analysis. *Agriculture Ecosystem and Environment* 204: 40–50.

USDA 2017. World Agricultural Production. Washington, DC.

Vance, C.P, Uhde-Stone, C and Allan, DL. 2003. Phosphorus acquisition and use: Critical adaptations by plants for securing a nonrenewable resource. *New Phytologist* 157:423–447

Walkley, A and Black, IA. 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.

Yasufumi, K, Yuriko K, Toshihiro, W, Jon, E, Shaff, H, Ohta, Leon, V, Kochian, Tadao W, Thomas, B, Kinraide, and Hiroyuki K. 2013. Molecular and Physiological Analysis of Al3+ and H+ Rhizotoxicities at Moderately Acidic Conditions, *Plant Physiology*, September 2013, Vol. 163, pp. 180–192

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