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Assessment of mean reduction in morphological trait of Ethiopian barley (*Hordeum vulgare L.*) genotypes grown under limed and unlimed soil at Holetta, Central Ethiopia

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Abstract: **Soil acidity is now a serious threat to barley production in most highlands of Ethiopia. Three hundred twenty (320) barley genotypes were evaluated in 2017 main-season, at Holetta Agricultural Research Center using 20x16 Alpha Lattice design under two-soil conditions (limed and unlimed). The objectives of the study were to evaluate the effect of soil acidity on morpho-agronomic traits. The analysis of variance (ANOVA) showed that there were significant differences among the genotypes under both limed and unlimed soil conditions for all traits except for days to emergence under limed soil conditions, indicating the presence of genotypic variation among the studied genotypes. Soil acidity stress caused reductions ranging from 0.41 % in thousand kernel weight to 40.40% in fertile tillers per plant.**

Keywords: **ANOVA, genotypic variation, soil acidity stress.**

1. INTRODUCTION

Barley*(Hordeum vulgare L.)* is the fourth most important cereal crop in the world after wheat, maize and rice (FAO, 2016), while in Ethiopia, it is sixth in yield (ton ha^{-1}) after Maize Wheat Sorghum Rice, and Finger millet with productivity of 2.18 ton ha^{-1} (CSA, 2019). It is an important crop grown in diverse agro-ecology from 1,500 to 3,500m altitude for many purposes in different seasons and production systems and a common food grain, especially for the highlands of Ethiopia (Berhane *et al*.,1996; Bantayehu, 2013).

In Ethiopia, about 43% of the Ethiopian high land with altitude of >1500 arable land are affected by soil acidity(Ethiosis,2014).It shows an increaent in covarage from the data of 2011 which is 40.9, this seriously affecting crop yields and agricultural productivity the productive highlands of the country (Hailu and Getachew, 2011*)*.The most important abiotic stress constraining the production of barley includes low soil fertility, low soil pH, poor soil drainage, frost and drought. From these abiotic stresses, soil acidity is one of the most important constraints in barley production, mainly on Nitisols or Oxisols, of the Ethiopian highlands where the rainfall intensity is high and crop cultivation has been carried out for centuries (Beyene,1987; Bekele and Höfner, 1993). Barley is considered to be more sensitive to acidic soils than rye, oat, rice and wheat (Bona *et al.,*1993).The acid tolerance order reported as maize> rye> triticale> wheat>barley (Polle and Konzak, 1985).

Soil acidity causes delay in barley germination and initiation. The principal factor responsible for delay emergence in acidic soil did not delay radical initiation, but delay initiation of hypocotyls elongation and these elongation of hypocotyls was highly associated with rate of tap root growth (Ritchey and Carter, 1993). Tiller numbers may also be reduced by poor nutrient availability. The higher number of effective tillers per plant was recorded in wheat plants that received higher levels of potassium (Baque *et al.,* 2006). Mean value of number of fertile tillers per plantin both limed and not limed soils is statically different and the limed have a higher mean value of fertile tiller (Temesgen, 2014). The number of tillers per plant significantly (P<0.05) differed between cultivars as well as lime treatments. The number of tillers per plant was higher for plants grown in lime treated soil than in lime untreated soil (Sisay and Balemi, 2014). Moreover, barley grown under acidic soil condition is remarkably shorter than lime treated soil. Plant height increased under lime treated soil; this is related to the increase in soil fertility and reduction of the toxic concentration of acidic cations (Chimdi *et al*., 2012).

Gallardo *et al*., (1999) reported that, the overall effect of soil acidity is significantly expressed on biomass and grain yield of crops. On barley 50% and 30% reduction of grain yield, respectively, for sensitive and tolerant cultivars when they were grown in naturally acidic soil (pH 4.9) with a large amount of extractable Al compared to that grown in non acidic soil (pH 5.8). The pH of the soil less than 5.5 results in very low yield of barley (0.5 ton ha^{-1}) compared with barley growing soils of the country (Bekele and Höfner, 1993).

Furthermore, non-amended acidic soil produced the lowest harvest index (HI). The increased percent in HI obtained on acidic soils treated with different lime rate as compared to respective controls (non amended). This is highly likely associated with reduction of concentration of exchangeable acidity and enhancement of exchangeable bases, CEC and available P of the soils (Chimdi *et al*., 2012). All limed treatments had higher mean values of thousand seed weight (TSW), number of seeds per spike (NSPS) and hectoliter weight (HLW) relative to no lime (Temesgen, 2014). The purpose of this study was to evaluate the effect of soil acidity on morpho-agronomic trait.

2. MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Holetta Agricultural Research Centre, which was located at 9^{o}00'N, 38^o 30'E at an altitude of 2400 m above sea level. It is 29 km away from Addis Ababa on the road to Ambo. Holetta Agricultural Research Centre had mean annual rainfall of 1044mm, mean relative humidity of 60.6%, and mean maximum and minimum temperature of 22.10°C and 6.20°C, respectively. The soil of the experimental field is clay classified as, Nitosol, which was characterized with pH of 4.58 and exchangeable acidity 2.50 cmol/kg for the unlimed experiment (HARC, 2017 Soil lab result).

Experimental Materials

A total of 320 barley genotypes, including 27 released varieties and 293 pure lines collected from the representative acid soils in different Zones of Ethiopia (Table 1). The materials with their passport data were obtained from Holetta Agricultural Research Centre.

Table 1. Zones, altitude ranges and number of accessions of the collected barley germplasm used for the study.

Altitude classes					
Zone of collection	**Class I <2000**	**Class II 2001-2500**	**Class III 2501-3000**	**Class IV >3000**	**Total**
Agew Awi	1	4	5	_	10
Arssi	6	4	10	5	25
Bale	5	5	6	3	19
South Gondar	1	5	5	4	15
South wello	1	6	10	2	19
SouthTigray	5	8	10		24
Gurage	2	5	12	8	27
Hadya	2	6	3	_	10
Keficho Shekicho	1	1	_	_	2

West Shewa	2	5	8	2	17
East Gojam	_	5	6	2	13
Eastharerge	1	6	6	_	13
EastShewa	_	1	_	_	1
EastWellega	1	10	5	_	16
East Tigray	4	8	6	2	20
North Omo	3	5	15	3	26
North Shewa	4	10	11	11	36
Released varieties	_	_	_	_	27
Total	39	94	118	42	2320

Soil Sample Collection, Chemical Analysis and Lime Application Procedures

Random soil samples were taken at a depth of 0-20 cm using a zigzag sampling pattern from experimental field before sowing and after harvest (Dan and Thomas, 2006). The collected samples were immediately air-dried and sieved to separate the roots and other unwanted materials from the soil and all samples were combined. Finally, composite sample was submitted for laboratory analysis. Soil pH was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5 soils to water ratio (Pam and Brian, 2007). Exchangeable cations (Ca, Mg, K and Na) and cation exchange capacity (CEC) were determined after leaching the soil samples with 1 M ammonium acetate solution at pH 7 (Chapman, 1965). Exchangeable acidity (Al^{3+}, H^+) was determined by saturating the soil samples with 1M KCl solution and titrated with 0.02 M NaOH (Abbott, 1989).

Before sowing the acid soil was ameliorated by lime ($CaCO_3$), to raise soil pH from acidic conditions to a target level that was optimized for the plant growth (Alatas *et al.*, 2005).The amount of lime required was calculated based on the formula of Hoskins (1997).

$$LR,\ CaCO_3\ (kg/ha) = \frac{EA\ (cmol/kg\ of\ soil) * 0.15m * 10^4\ m^2 * B.D\ (Mg/m^3) * 1000}{2000\ cmol/kg}$$

Where: EA= exchangeable acidity, expressed in Cmol/kg of soil0.15 m plowing depth.

Total volume of hectares of soil = area ($10000m^2$)*Depth (0.15m)

B.D = bulk density taken as 1.1 g/cm^3 for loam soil textural class.

Then multiplied by a crop coefficient factor for soil acidity which is 2.0 = for Al-sensitive crops (barley belongs to these groups).

Experimental design and procedures

The study was conducted on two soil acidity conditions (unlimed and limed soils) as two separate experiments laid out in 20x16 Alpha Lattice Design with two replications for each experiment. Plots consisted of four rows each 2.5m long by 0.8m width ($2m^2$). Each plot had 0.2m spacing between rows. The spacing between plots, blocks in each replication and between replications were 0.5m, 1.0m and 1.0m respectively. The seed rate was $85kgha^{-1}$and fertilizers were applied during planting in the form of Urea and Diamonium phosphate (DAP) at the rate of 41 and $46kgha^{-1}$ respectively. The experiment was planted in the first week of July 2017. All field management practices were handled as per the recommendation for barley production.

Data collection

Crop phenology like days to emergence (DTE), days to heading (DTH) and days to maturity (DTM) were counted from the date of planting to 50% seedling emergence and from the date of emergence to 50% heading and 75% physiological maturity of plants in each plot respectively. The average plant height (PH) was measured from the ground to the tip of spikes of five main plants of the two middle rows of each plot. Disease scoring on barley leaf scaled and net blotch disease was assessed by visual examination using a scale of 0 to 9 according to (Saari and Prescot, 1975). Yield

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components such as fertile tillers per plant (FTP), spike length per plant (SLP) and kernels per spike (KPs) were determined from five random plants of the middle rows of each plot. After harvesting, indiscriminately counted thousand kernel weight (TKW) from each plot were weighted and adjusted to 12.5% standard grain moisture content of cereals, while hector liter weight (HLW) was measured after drying the grain of each plot up to 12.5% moisture content. The total above ground biomass yield (BY) harvested from the middle two rows of each plot was dried out for some days under sun and then weighted. The grain yield (GY) was harvested from the middle two rows of each plot and adjusted to the standard grain moisture content (12.5%).

Analysis of variance (ANOVA)

Data were analyzed by restricted maximum likelihood (REML) to fit a mixed model with Genotypes, Replications and Blocks within replication as random effects. The REML model produced best linear unbiased predictors (BLUPs), which is a standard method for estimating random effects of a mixed model. PROC MIXED was conducted to estimate genotypes as well as residual variance components. Analyses of variance (ANOVA) was done using the SAS statistical package (SAS, 2004) using the following linear model.

model: $Y_{ijk} = \mu + g_i + r_j + b_{kj} + \varepsilon_{ijk}$

Where Y_{ijk} = the response of Y trait from the i^{th} genotype, grown in the k^{th} incomplete block of j^{th} replicate, =general mean, g_i=random effect of the i^{th} genotype, r_j= random effect of the j^{th} replicate, b_{kj} = random effect of k^{th} incomplete block in a j^{th} replicate, ε_{ijk} =experimental error.

3. RESULTS AND DISCUSSION

Effect of Lime Application on Soil Acidity Related Chemical Properties of the Soil

The soil chemical analysis result after harvest for some chemical properties are presented in Table 2. The Soil acidity changed from strongly acidic to slightly acidic classes and the deficiency of certain plant nutrients were observed. The application of lime raised the soil pH to 6.24 and dropped exchangeable acidity from 1.71 to 0.21(cmol/kg) under unlimed and limed respectively.

The organic carbon (OC) content was 1.29 and 1.54 % under unlimed and limed soil, which is medium according to Baize (1993) who categorized OC content as very low (<0.06%), low (0.60–1.25%) and medium (1.26–2.50%). This have an impact on the availability of organic matter content in the soil. The values for total nitrogen (N) was 0.13 and 0.16% under limed and unlimed soil. According to Landon (1991), these values were rated as low. The available phosphorus (P) was 12.68 and 17.89 mg/kg under unlimed and limed soil, respectively. Landon (1991) categorized available P as high (> 50 mg/kg), as medium (15 – 50 mg/kg) and as low (< 15 mg/kg). Based on this classification, available P of limed soil was grouped as medium and unlimed as low.

The Cation Exchange Capacity (CEC) was 21.98 and 24.99 (cmol/kg) under unlimed and limed soil. According to Landon (1991), soils had optimum CEC values. Liming also affected exchangeable Al, exchangeable bases (Ca, Na, Mg and K), Available Micronutrient (Zn, Fe and Mn) (Table 2). This result was in agreement with the result of Effiong *et al*., (2006) indicated that an increase in the exchangeable bases as a result of lime application to soils. Sisay and Balemi (2014) who also reported that reclaiming acid soils by liming had a significant effect on selected soil chemical properties of soil.

Table 2. Selected chemical properties of the experimental soil

Soil properties	Limed soil	Un limed soil
pH(H_2O 1:2.5)	6.24	4.69
Nitrogen (%)	0.13	0.16
Organic carbon (%)	1.29	1.54
Available phosphorus (mg/ kg soil)	17.89	12.68
Exchaneable acidity (cmol/kg)	0.21	1.71
Cation exchangable Capacity (cmol (+)/ kg)	24.99	21.98
Exchangable Al (meq/100g soil)	0.09	1.25

Exchangeable Ca (cmol(+)/kg)	7.90	4.35
Exchangeable Mg (cmol(+)/kg)	3.09	0.78
Exchangeable Na (cmol(+)/kg)	0.07	0.04
Exchangeable K (cmol(+)/kg)	0.71	0.25
Micro nutrient Zn(ppm)	0.93	1.35
Micro nutrient Fe(ppm)	146.18	224.82
Micro nutrient Mn(ppm)	37.81	55.50

Analysis of variance for some morpho-agronomic traits

The significant difference ($p<0.01$) was observed among genotypes for all evaluated traits under both soil conditions except days to emergence under limed soil (Table 3 and 4). This indicated the existence of significant genetic variability among landrace, improved varieties and between landrace and improved varieties for the expression of their traits under limed and unlimed soil. This in turn provides ample scope for selecting superior acid soil tolerant barley landraces and improved varieties.

From three hundred twenty genotypes one hundred twenty three genotypes gave higher grain yields than grand mean (2772.45 kg/ha) under limed soil. Besides, one hundred nineteen genotype gave a higher grain yield than grand mean (2392.42 kg/ha) under unlimed soil. Under limed soil condition, biomass yield exhibited the widest range (4341.17 to 18625.80 kg/ha) followed by grain yield (1402.32 to 6819.78 kg/ha), plant height (74.37 to 121.12 cm) and days to heading (41.49 to 87.07 days). Similar patterns were observed under unlimed soil that biomass yield exhibited the widest range followed by grain yield (796.82 to 5125.16 kg/ha), plant height (67.71 to 113.95 cm) and days to heading (42.64 to 86.26 days). Genetic diversity of barley has also been reported by Ebrahim *et al*. (2015) indicate that grain yield exhibited the widest range (2258 to 6202 kg/ha) followed by biomass yield per plot (1483 to 2733 gm), plant height (82.9 to 118.1 cm) and days to maturity (110.3 to 137 days) and also Derbew *et al.* (2013) had similar reports under non stress growing condition.

Genotypes Shege, HB-1307, Acc-24970, Acc-233040-A, HB -1966, HB - 42, Ardu 12-60B, Ahore 880/61, EH -1847 and HB -1963 under limed soil and genotypes HB-1966, Shege, Ibon174/03, Acc-24990, Acc- 17148, Ahore 880/61, Acc-3514-A, Acc-222969-C, HB-42 and HB -1307 under unlimed soil had yields higher than other genotypes.

Table 3. Expected mean squares of some morphological and agronomic trait of barley genotypes grown under limed soil at HARC, 2017

Trait	Genotype (Df=319)	Rep(Df=1)	Block (rep) (Df=38)	Error (Df=281)	CV	Mean
DTE	0.07 ns	52.51 ns	0.13*	0.07	4.49	5.71
DTH	155.30**	954.41 ns	4.37*	3.64	3.16	60.29
DTM	176.54**	1154.69 ns	17.15 ns	16.37	3.97	101.90
Scald	2.61**	13.86 ns	0.65**	0.53	11.13	6.56
N. Bloch	4.28**	12.80 ns	0.87**	0.79	17.57	5.05
FTP	0.77 **	16.83 ns	0.32**	0.28	11.80	4.48
SLP	1.73 **	110.30 ns	0.48**	0.39	8.72	7.18
PH	120.32 **	6177.08 ns	31.39**	23.19	4.60	104.79
KPS	266.79**	626.79ns	27.78**	25.24	14.67	34.23
GY	2400093.84**	19932974.00ns	266094.00*	242424.00	17.76	2772.45
BY	22638721.16**	741287174.00ns	4654534.00**	34832580.00	20.27	9203.91
HI	0.01**	0.36ns	0.03**	0.003	16.52	0.32
TKW	68.41 **	252.17 ns	5.61 ns	5.61	6.53	36.25
HLW	36.15 **	302.71 ns	10.87 ns	10.85	5.42	60.76

Table 4. Expected mean squares of some morphological and agronomic trait of barley genotypes grown under unlimed soil at HARC, 2017

Trait	Genotype (Df=319)	Rep (Df=1)	Block (rep) (Df=38)	Error (Df=281)	CV %	Mean
DTE	0.02 **	3.94 ns	0.08**	0.01	1.59	6.92
DTH	162.68 **	11.81 ns	17.40*	10.79	5.31	61.77
DTM	266.24 **	32.31 ns	52.00*	29.56	5.09	106.74
SC	4.97**	25.74ns	0.73**	0.63	11.57	6.86
N. Bloch	2.63**	27.56ns	0.66**	0.55	15.58	4.74
FTP	0.86 **	30.28 ns	0.30**	0.23	17.96	2.67
SLP	1.72 **	26.40 ns	0.60**	0.54	10.58	6.92
PH	198.48 **	11956.88 ns	113.81**	79.26	9.30	95.69
KPS	205.64 **	681.39 ns	28.36 ns	27.20	16.90	30.85
GY	2115657.91 **	11274139.00ns	269019.00*	243201.00	20.59	2392.42
BY	22452205.28**	110870239.00ns	3575519.00*	3299627.00	20.56	8706.68
HI	0.01 **	0.02ns	0.02*	0.002	16.22	0.29
TKW	70.48 **	332.77 ns	8.39 ns	7.95	7.87	36.10
HLW	44.82 **	13.70 ns	13.70*	12.59	5.96	59.57

*,**=significant at 0.05 and 0.01 of probability levels, respectively, ns= non-significant, Df= degree of freedom, DTE = Days to emergence, DTH = Days to heading, DTM = Days to maturity, SC = scald, N.Bloch= Net bloch, FTP = Number of fertile tillers per plant(count), SLP = Spike length (*cm*), PH = Plant height (*cm*), KPS = Number of kernels per spike (count), GY= Grain yield (kg/ha), BY= Biomass Yield(kg/ha), HI = Seed harvest index, TKW= Thousand kernel weight (gm), HLW= Hectolitre weight (kg/hl), CV= coefficient of variation

Effect of soil acidity on phenology and growth of barley genotypes

The phenology and growth performance of barley genotypes grown under limed and unlimed soils are presented in (Table 5). Results showed that acidic soil had a reduction effect on agro-morphological traits of the studied barley genotypes compared to limed soil such as, delay of days to emergence, days to heading and days to maturity, decrease of plant height and increase severity of foliar diseases.

The days to seedling emergence of genotypes under limed soil ranged from 5.71 days to 5.73 days, while under unlimed soil ranged from 6.85 days to 7.25 days (Table 6). Soil acidity delayed seedling emergence by 1.21 or by 21.2% days from limed soil (Table 5). Lime hastened emergence of barley because it creates normal growing conditions. Similar reports by Lynch (1980) and Ritchey and Carter (1993) indicated that the initial adverse effects of Al^{+3} toxicity are inhibiting root elongation and causing structural damages to the root tissues, which were followed by limiting water uptake and nutrient absorption.

Genotypes were showing different response to soil acidity in days to heading (DTH) and days to maturing (DTM) under both limed and unlimed soils. DTH of genotypes were ranged from 41.49 to 87.07 days in limed soil, and from 42.64 days to 86.26 days in unlimed soil. DTM of genotypes were ranged from 84.72 to 119.33 days in limed soil, and from 84.83 days to 126.13 days in unlmed soil (Table 6). Under unlimed soil condition DTH and DTM were delayed by 1.48 or by 2.45% and 1.83 or by 1.80% from limed soil respectively (Table 5). Hirpa *et al*. (2013) had similar report that shows there were significant difference between genotypes grown under limed and unlimed soils, where genotypes in limed soil have lower number of days to heading and maturity than unlimed soil.

The variation in plant height (PH) among genotypes under both limed and unlimed soils showed that, genotypes under limed soil was taller than genotypes grown in unlimed soil. The plant height of genotypes in limed soil was ranged from 74.37 to 121.12 cm, while in unlimed soil, it was between 67.71 and 113.95 cm (Table 6). The mean difference between limed and unlimed soil explained that PH under limed soil condition had 9.10 cm or 8.68 % of taller from unlimed soil (Table 5). The increment in plant height in response to the application of lime was because lime neutralizes the toxic effect of acid soil and increase soil nutrient availability by enhancing mineralization. Grant *et al*. (2001) reported that symptoms of P deficiency under unlimed soil include decreased of plant height. Sisay and Balemi (2014) reported that plant height was higher under lime treated than untreated soil conditions.

The severity of scald disease on barley genotypes was higher by 0.30 or by 4.57% in unlimed soil as compared to severity of scald in limed soil (Table 5). The severity of scald disease of genotypes in limed soil ranged from 2.43 to 7.48, while in unlimed soil it ranged from 1.64 to 9.06 (Table 6). Severity of net blotch decreased by 0.31 or by 6.13% from limed soil (Table 5). The severity of net blotch disease of genotypes in limed soil ranged from 4.64 to 5.46, while in unlimed soil it ranged from 4.63 to 4.94 (Table 6).Similar finding by Huber (2012) states that plants with an optimal nutritional status have the highest resistance to disease and that susceptibility increases as nutritional status deviates from the optimum. In contrast, high nutrient supply stimulates disease severity, is typical for an obligate parasite, such as leaf blotch in spring barley.

Effect of soil acidity on yield and yield components of barley genotypes

Soil acidity had a significant effect on yield and yield components of barley genotypes (Table 5). Genotypes grown in unlimed soil had low number of fertile tillers per plant, spike length, numbers of kernels per spike, grain and biomass yields, harvest index, thousand kernel weight and hectoliter weight comparing to genotypes grown in limed soil.

Acidic soil stress caused a significant decrease in number of fertile tillers per plant. The number of fertile tillers per plant was in the range of 3.61 and 5.62 in limed soil, and from 1.53 to 3.95 under unlimed soil (Table 6). Fertile tillers per plant was reduced under unlimed soil with 1.81 or by 40.40 % from limed soil (Table 5). Genotypes grown under limed soil produced relatively higher number of fertile tillers per plant compared to those genotypes that were grown under unlimed soil. According to Baque *et al.* (2006) availability of potassium under limed soil was increased the number of fertile tillers per plant. Sisay and Balemi (2014) reported that fertile tillers per plant was higher under lime treated than untreated soil condition. Under lime untreated soil fertile tillers ranges from 3 tillers to 8 tillers per plant; Similarly, under lime treated soil fertile tillers ranges from 10 tillers to 11 tillers per plant.

There were differences among genotypes in spike length under both limed and unlimed soils. The spike length of genotypes in limed soil ranged from 4.94 to 9.47 cm and in unlimed soil, it ranged from 4.87 to 8.54 cm (Table 6). The average spike length was reduced from 7.18 cm in limed conditions to 6.92 cm or by 3.62% under unlimed soil conditions (Table 5). El-Hashash and Agwa (2018) had a similar report indicating that spike length is reduced from 18.69 under nonacid soil stress to 16.16 cm under acid soil stress.

Genotypes were different in response to number of kernels per spike under both soil conditions. The number of kernels per spike ranged from 17.58 to 58.16 under limed soils, and from 18.58 to 55.49 under unlimed soils (Table 6). The average number of kernels per spike was reduced from 34.23 under limed conditions to 30.85 under unlimed conditions or by 9.87% (Table 5). According to Grant *et al*. (2001), barley genotypes under unlimed soil respond to phosphorus deficiency by minimizing the production of some viable seeds. Phosphorus deficiency decreases the number of seeds produced per spike. The reduction in seed number occurs through reduced numbers of fertile spikelets per spike.

Acidic soil stress led to a decrease in grain yield, biomass yields and harvest index. Grain yield ranged from 1402.30 to 6819.78 under limed soils, and from 796.82 to 5125.20 under unlimed soils, biomass yield ranged from 4341.17 to 18625.80 under limed soils, and from 3246.46 to 17114.4under unlimed soils and harvest index was ranged from 0.20 to 0.41 under limed soils, and from 0.17 to 0.50 under unlimed soils (Table 6). Under unlimed soil grain yield was reduced by 380.03 kg/ha or by 13.70%. Biomass yield was reduced by 497.23 kg/ha or by 5.40%. Harvest index reduced by 0.03 or by 9.38% from limed conditions (Table 5).

The highest barley grain and biomass yields and harvest index under limed soil was due to application of lime. Limes reduce the toxic effect of Al^{+3} and increase availability of different nutrients. Gallardo *et al*. (1999) also reported that grain yield reduction of 50% and 30% in Al sensitive and tolerant varieties of barley were observed when grown under acidic soil, respectively. Boke and Fekadu (2014) also reported the highest mean grain yield of barley was obtained from treatments received a lime application.

Thousand kernel weight (TKW) under unlimed soil was reduced by 0.15 gm from limed soil (Table 5). Rahman *et al.*(2005) had a similar report on application of lime, increasing the wheat thousand kernel weight by 3.70gm from unlimed soil.

Acidic soil stress led to a significant decrease in hectoliter weight (HLW). HLW was reduced by 1.19 $kghl^{-1}$. Well-filled and plump barley grains were obtained under limed compared to unlimed soil. Hectoliter weight is most often influenced by acid soil stress that decrease the rate of grain filling and results in lower test weights at harvest (Mike, 2012). Temesgen (2014) reported that hectoliter weight (HLW) had higher mean values under limed soil as compared to unlimed soil.

Table 5. Effect of acidic soil stress on mean performance of various traits of barley genotypes at Holeta Agrcultural Research Center in 2017

Trait	Mean under limed	Mean under unlimed	Change compared to limed	%
DTE	5.71	6.92	-1.21	21.20
DTH	60.29	61.77	-1.48	2.45
DTM	101.90	103.74	-1.84	1.80
SC	6.56	6.86	-0.30	4.57
N.Bloch	5.05	4.74	0.31	6.13
FTP	4.48	2.67	1.81	40.40
PH	104.79	95.69	9.10	8.68
SLP	7.18	6.92	0.26	**3.62**
KPS	34.23	30.85	3.38	9.87
GY	2772.45	2392.42	380.03	13.70
BY	9203.91	8706.68	497.23	5.40
HI	0.32	0.29	0.03	9.38
TKW	36.25	36.10	0.15	0.41
HLW	60.76	59.57	1.19	1.96

Table 6. Statistical data recorded with 14 agronomic traits for 320 barley genotypes grown under limed and unlimed soil

Trait	limed soil			Unlimed soil		
	Mean± SD	Min	Max	Mean± SD	Min	Max
DTE	5.71±0.01	5.7	5.73	6.92±0.03	6.85	7.25
DTH	60.29±8.88	41.5	87.1	61.77±8.69	42.64	86.3
DTM	101.90±8.81	84.72	119.3	106.74±10.59	84.83	126.1
SC	6.56±0.94	2.4	7.5	6.86±1.42	1.6	9.06
N. Bloch	5.05±0.17	4.6	5.5	4.74±0.06	4.6	4.92
FTP	4.48±0.41	3.6	5.62	2.67±0.51	1.5	4
SLP	7.18±0.74	4.94	9.47	6.92±0.66	4.87	8.5
PH	104.79±6.45	74.37	121.1	95.69±6.16	67.71	114
KPS	34.23±10.80	17.6	58.16	30.85±9.09	18.57	55.5
GY	2772.45±1021.68	1402.3	6819.78	2392.42±962.56	796.82	5125.2
BY	9203.91±2995.79	4341.17	18625.8	8706.68±3077.04	3246.46	17114.4
HI	0.32±0.04	0.2	0.41	0.29±0.06	0.17	0.5
TKW	36.25±5.56	24.95	57.06	36.10±5.44	24.8	55.3
HLW	60.76±3.14	53.91	75.45	59.57±3.51	52.41	74.44

DTE = Days to emergence, DTH = Days to heading, DTM = Days to maturity, SC = scald, N. Bloch= Net Bloch, FTP = Number of fertile tillers per plant(count), SLP = Spike length (*cm*), PH = Plant height (*cm*), KPS = Number of kernels per spike (count), GY= Grain yield (kg/ha), BY= Biomass Yield(kg/ha), HI = Harvest index, TKW= Thousand kernel weight (gm), HLW= Hectoliter weight (kg/hl)

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4. CONCLUSION

Soil acidity is now a serious threat to barley production in most highlands of Ethiopia. The extent of acidity is increased by 2.1% within the past three decades, mainly due to continuous cropping system and use of acidifying fertilizers. Influence of acid soil had started from early phenological trait to final yield. But the degree of effect is different from trait to trait, but in all casees the early influence was shown on final yield components as well as grain quality of barley. Acid soil stress tolerance in barley is complex by using morphological trait, but it gives the direction to improve these studies by using more advanced molecular technologies to select tolerant barley genotypes from several accessions preserved in the gene bank of Ethiopia and to give the answer for barley growing community of Ethiopian highland.

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