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Growth, Phenology and Yield Component of Barley (*Hordeum vulgare* L.) Genotypes as Affected by Fertilizer Types Under Acidic Soil

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Abstract: Field experiment was conducted on acidic soil of Hagereselam, southern Ethiopiain 2019 cropping season to evaluate the growth and yield component formation performance of barley genotypes under different inorganic fertilizer types. Treatment consisting 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 laid out using a Randomized Complete Block Design with factorial arrangement with three replications Both main and interaction effects influenced days to physiological maturity, plant height, number of effective tillers m^{-2}. However, days to heading, spike length, number of grain per spike and1000 grain weight, were only affected by main effects. Barley Genotype 217176b with NPSB fertilizer exhibited the longest plant height and better performance with regard to the remaining measured parameters. However, it did not significantly differ for the same parameters from the same genotype under NP and genotype 240478 with NPSB fertilizer application. The lowest performances were recorded from genotype 208855b with no fertilizer application. Given the fact that the performance of growth, phenology and yield components 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 is very essential for appropriate production of barley under acidic soils of Hagereselam and acidic soils of similar agro-ecologies in the highlands of Ethiopia.

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

1. Introduction

Barely (Hordeum Vulgare L.) is one of the most important food crops produced in the world and ranking fourth in production area next to wheat, maize and rice [5]. It is the fifth important crop after maize, teff, sorghum and wheat in the Ethiopia [5]. Its grain is used for the preparation of different foodstuffs, such as injera, kolo, and local drinks, such as tela, borde and beer. The straw is used as animal feed, especially during the dry season. The national average yield of barley in Ethiopia is low (2.2 ton ha^{-1}) [5].

Soil acidity is a critical issue requiring urgent attention in most highlands of Ethiopia because of its impact on crop production and productivity [15]. Soil acidity is a critical issue requiring urgent attention in most highlands of Ethiopia because of its impact on crop production and productivity [16]. The use of N fertilizers in the form of ammonia is a source of acidification [9]. The problem is common in all regions where precipitation is high enough to leach appreciable amounts of exchangeable bases from the soil surface [1]. According to [17] acidic soils tend to be deficient in N, P and S which result in sever yield loses and deteriorated nutritional quality of the crops. Most acidic soils have poor chemical and biological properties. Its acidity associated with Al, H, Fe, Mn toxicities to plant roots in the soil solutions and corresponding deficiencies of the available P, Mo, Ca, Mg and K [13]. At pH below 5, Al is easily soluble in water and becomes the dominant ion in the soil solution. Soil acidity is expanding in scope and magnitude in Ethiopia, severely limiting crop production. For example, in barley, wheat and faba bean growing areas of central and southern Ethiopian highlands, farmers have shifted to producing oats which is more tolerant to soil acidity than wheat and barley [12].

Several practices have been recommended to reclaim soil acidity and upgrade the productivity of strongly acidic soils. These include the cultivation of acid tolerant varieties, covering the surface with non-acidic soil, the use of organic fertilizers, mineral fertilizers in a harmonized combination for sustainable production and liming for soil quality. However, continuous lime in soil is expensive and environmentally risky [26]. In this regard, the application of adequate mineral nutrition and use of acid tolerant varieties would be a suitable strategy for increase soil acidity related yield reduction. 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 growth, phenology and yield components of barley under acidic soil at the study area.

2. Materials and Methods

2.1. Description of Study Site

This study was conducted at Hagerselam, southern Ethiopia during the main cropping seasons of 2019. Hagerselam is located at 38° 27'44''E longitude and 06° 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.

2.2. Soil Analysis

For soil analysis, before planting twenty soil samples were randomly taken from the experimental site at a depth of 0- 20 cm using an auger and the samples were mixed thoroughly to produce one representative composite sample of 1kg. Samples were also taken later at harvest from each plot and composite same of 1kg was produced on treatment basis rather than plot base.

2.3. Experimental Methods

Factorial experiment consisting of four fertilizer types (control, DAP, NPS, NPSB), and four barley genotypes from Ethiopian Biodiversity institute (217176b, 240478 and 234911b 208855b) and one variety (HB-1307) were used as experimental material.

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 1m, respectively. The plot size was 1.6 x 1.5 m (2.4 m^2) accommodating eight rows of barley 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 DAP at100 kg ha^{-1} fertilizer were applied as basal dressing at the time of sowing barley.

Table 1. *Description of varieties used in this study.*

Genotypes	Collected area		
	Region	**Keficho Shekicho**	**Woreda**
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 Centre at 206		

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})
Control	46	0	0	0
NP	64	46	-	-
NPS	65	38	7	-
NPSB	64.9	37.7	6.95	0.1

2.4. Data Collection and Analysis

Days to emergence, Day to heading and Days to maturity were determined by counting the number of days from sowing to the time when the plants reached to each of phonological stage through visual observation. Five plants were randomly selected and plant height was measured at physiological maturity from the ground level to the tip of panicle from middle six harvestable rows in each plot

Spike length was measured by selecting five plants randomly from six rows at the node where the first spike branches emerge to the tip of the spike, then averaged. At stage of grain setting, the numbers of effective 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 and The weight of 1000 seeds was determined by carefully counting the grains and weighing them using a sensitive balance.

2.5. Data Analysis

Data 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.

3. Results and Discussions

3.1. Physico-Chemical Properties of the Study Soil

According to the laboratory analysis, the soil texture of the experimental area was dominated by clay. Thus, the texture of the soil was clay loam (table 3). The pH of the soil was 4.48 (Table 3) which was strongly acidic [25, 4] 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%. [14] 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. Total nitrogen value of the experimental soil was (0.14). According to EthioSIS [8] 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. Available P content of the experimental sit was 4.21 mg kg^{-1} (Table 3). EthioSIS [8] Suggest optimum P content for most Ethiopian soil as 15 mg kg^{-1}. This low phosphorous content is due to intensive mining of the farm fields and fixation by heavy metals (Al, Fe and Mn). [12] Reported that under acidic soil low content of P was due to fixation problem.

The CEC of the site was 19.78cmol kg^{-1} (Table 3). [14] 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 2). According to [8] 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

3.2. Crop Phenology

3.2.1. Days to Emergence and Heading

Days to emergence was significantly (P≤ 0.001) affected by genotypes but not by the types of inorganic fertilizers and the interactions. The mean numbers of days required for emergence were between 6 to 9 days for the tested genotypes (Table 3). 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 due to 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 [22] who reported that plants depend mostly on stored food than on external nutrients for germination and early establishment.

Days to heading was significantly (P ≤ 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, [2] reported that barley genotypes differ in days to heading. This result is also in line with the findings of [2] 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 4). 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 [7] who suggested that that the supply of N and P contribute to vigorous, rapid growth and early heading of wheat crop.

Table 4. *Main Effects of Inorganic Fertilizers and Barley Genotypes on Days to Emergence and Heading under Acidic Soil, during cropping season of 2019.*

Treatments	Day to Emergence	Day to Heading
Types Fertilizers		
Control	8	78a
NP	8	73b
NPS	8	72b
NPSB	8	71b
Fertilizers	ns	***
LSD	2.9	1.15
Genotypes		
217176b	7c	65e
240478	6d	56d
234911b	8b	72c
208855b	9a	81b
HB- 1307	9a	93a
Genotypes	***	***
Genotypes* Fertilizers	ns	ns
CV	2.89	2.13
LSD	0.19	1.29

Means followed by the same letters are not significantly different at (P ≤ 0.05)

3.2.2. Effects of Inorganic Fertilizers on Days to Physiological Maturity of Barley

Days to physiological maturity was significantly (P≤ 0.001) affected by the main effects of genotypes, the types of inorganic fertilizers and by their interaction (Table 4). 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 no fertilizer application. 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 days to physiological maturity may be attributed to their genetic difference, which reflects their variable response to environmental conditions. Similarly, [28] reported that genotypes could differ in days required to attain at physiological maturity.

3.3. 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 4)., mean value of genotypes for plant height 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 zero fertilizer application. The variation in the response may be due to differences in genetic makeup among the genotypes tested. [22] 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, plant height, root collar diameter, and chlorophyll content in barley [20]. This result is in agreement with [18] and [27] who reported that plant height of barely was increase with application of N fertilizer. In line with this result, [6] 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 [24].

3.4. Number of Effective Tillers

The data revealed significant difference ($P \leq 0.001$) due to interaction effects of genotypes with types of inorganic fertilizers on effective tiller number. Higher 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 Recommended 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 no applied fertilizer (Table 5). Generally, genotype 217176b tended to respond better to NSPB, NP, and NPS fertilization and also genotype 240478 for NPSB. This might be attributed to the different capacity of the genotypes in tillering and also due to nutrition. This is in agreement with that of [23], who reported significant difference among varieties for tillering. In line with this result, [11] reported that N and P fertilizer had potential role in number of total and effective tiller production per plant.

This variation could also happen 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 [24]. Similarly, [3] 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.

Table 5. *Interaction Effect of Barley Genotypes and Types of Inorganic Fertilizers on day to maturity Plant Height and Number of Effective Tillers.*

Treatments	Day to maturity	Plant height (cm)	Effective tiller (m^{-2})
217176b NPSB	82^{gh}	110.28^{a}	69.33^{a}
NP	83^{fg}	109.03^{a}	65.33^{ab}
240478 NPSB	77^{i}	108.86^{a}	65.0^{ab}
NP	79^{hi}	$102.7ab^{c}$	59.3^{bcd}
217176b NPS	82^{gh}	$105.95a^{b}$	62.3^{abc}
240478 NPS	83^{fg}	$98.2b^{c}$	58.6^{bcd}
234911b NPSB	84^{f}	94.98^{cd}	55.3cd
NP	85^{fg}	87.51^{de}	54.0^{d}
NPS	86^{f}	85.59^{ef}	53.3^{d}
HB-1307 NPSB	120^{b}	79.497^{fg}	36.33^{ef}
NP	120^{b}	76.25^{gh}	36.0^{ef}
NPS	120^{b}	75.98^{gh}	36.0^{ef}
208855b NPSB	99^{d}	79.843^{efg}	27.3^{gh}
NP	100^{d}	75.807^{gh}	24.6^{gh}
NPS	102^{d}	74.673^{gh}	24.66^{gh}
217176b control	90^{e}	71.24^{gh}	35.667^{ef}
240478 control	$85f^{g}$	73.81^{gh}	38.66^{e}
234911b control	92^{e}	66.77^{hi}	30.33^{ef}
HB-1307 control	140^{a}	62.89^{i}	28.3^{gh}
208855b control	106^{c}	68.61^{hi}	22.66^{h}
Interaction		***	***
CV	2.306	5.69	9.55
LSD	3.73	8.16	7.01

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

3.5. Spike Length

Spike length was significantly ($p < 0.001$) influenced by the main effects of inorganic fertilizers and genotypes, but not, by the interaction effect (Table 5). Genotype 217176b and 240478 produced longer spike length, however, the two genotypes do not differ for for the spike length 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 [6]. (2011), [10] who reported that the spike length of wheat significantly increased as a result of applying B blended fertilizer with macro nutrients. [3] Also reported that, optimum application of balanced nutrients has significant effect on spike length growth.

3.6. 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 6). 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. Reports have shown the variation in number of grain per spike as a function of differences in barely genotypes [21]. This result is also in agreement with that of [21] 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 6). This could be due to enhanced uptake of nitrogen, phosphorus and sulfur resulting from blending the nutrients with Boron. [7] 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 [6] reported that Boron application enhanced a significant improvement in the number of seeds per spike of wheat.

3.7. Thousand Grain Weight

Analysis of variance revealed that thousand-grain weight 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 5). 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, [19] 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 6. *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.*

Treatments	Spike length	Grain per spike	1000 grain weight
Fertilizers types			
NPSB	9.9093^{a}	41.901^{a}	37.5120^{a}
NP	9.4320^{ab}	39.351^{b}	36.2160^{ab}
NPS	8.8880^{b}	38.416^{b}	35.5847^{b}
Control	6.7213^{c}	26.120^{c}	20.9560^{c}
Fertilizer	***	***	***
LSD	0.72	2.33	1.47
Genotypes			
217176b	10.9858^{a}	46.231^{a}	38.0333^{a}
240478	10.3292^{a}	43.502^{b}	35.9700^{b}
234911b	8.2367^{b}	39.474^{c}	31.1600^{c}
208855b	6.8425^{c}	32.723^{d}	29.9300^{c}
HB- 1307	7.294^{c}	20.306^{e}	27.7425^{d}
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. Conclusion

Information on barley response to inorganic fertilizer types is crucial to come up with barley production under acidic soil. To evaluate the performance of barley genotypes in terms of growth, phenology and yield components with inorganic fertilizer types under acidic soil. The day to emergence, the day to heading were affected by the main effects. But day to physiological maturity was affected by interaction effect. The tallest plant height and highest mean number of effective tillers m^{-2} 217176b at NPSB, NP and NPS respectively without significant difference among each other and also genotype 240478 with NPSB. Genotypes 217176b and 240478 treated with NPSB and NP produced longer spike. The highest mean numbers of grain per spike and thousand-grain weight were recorded from genotype 217176b and recommended rate of NPSB as well as NP.

Given the fact that growth, phenology and yield components of barley between the two genotypes in combination with either NPSB or NP can be recommended for production of barley in acidic soils of Hagereselam and similar agro-ecologies in the highlands of Ethiopia. Therefore, it would be too early to reach at a conclusive recommendation since the current study was carried out only in one location for one cropping season. Hence, further studies replicated over seasons and across locations are needed to recommend optimum types of inorganic fertilizer with better growth, phenology and yield components to come up with improved productivity of barely varieties.

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