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ARTICLE *in* MIDDLE EAST JOURNAL OF SCIENTIFIC RESEARCH · JANUARY 2016

DOI: 10.5829/idosi.wjas.2014.10.5.1822

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Middle-East Journal of Scientific Research 23 (12): 2888-2894, 2015
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2015.23.12.22767

Performance Evaluation of Introduced Barley (*Hordeum vulgare* L.) Germplasm for Yield and its Related Traitsat Atsbi, Ofla and Quiha, Northern Ethiopia

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Abstract: Sixty four barley genotypes were tested in 8x8 simple lattice design at Atsbi, Ofla and Quiha environments in Tigray region. The objective of the studywas to evaluate the performance of barley germplasm for yield and its related traits. Analysis of variance revealed that there was a significant difference ($p< 0.001$) among the sixty four genotypes for all the characters studied except for 1000-kernel weight at Quiha which was significant ($p<0.05$) and plant height was non-significant at Atsbi and Ofla.It was observed that the overall mean for grain yield was the lowest (9.58 qt/ha) at Quiha environment, whereas Ofla seems to be ideal for cultivation of barley as the overall mean grain yield of the location was 36.13 qt/ha which is the highest among the three locations

Key words: Germplasm · Grain yield · Kernel weight

INTRODUCTION

Barley is a main food crop in the highlands and marginal areas where other cereals cannot grow, as well as animal feed and forage around the world. It is an important industrial crop providing raw material for malt, which is used for beer and whisky production. Barley grain contains 3 to 7% β-glucan, an important dietary fiber [1] that has significant blood cholesterol lowering effects [2-16]. Barley plays an important role in ensuring food security, as it requires relatively low input. Its yield stability is far better than other cereals, making it a dependable source of food in bad seasons [6].

The most important factors that reduce yield of barley in Ethiopia are low-yield capacity of farmers' varieties (landraces) and an inadequate number of improved varieties adapted to the different production systems and varied agro-ecological zones [4], poor agronomic practices, poor soil fertility, low soil pH, drought, water logging and frost. The major biotic constraints are diseases such as scald (*Rhynchosporium secalis* Oud.), net blotch (*Helminthosporium teres* Sacc.), spot blotch (*Helminthosporium sativum* Pum.) and leaf rust (Puccinia hordei Otth.); insect pests including Russian wheat aphid (*Diuraphis noxius*), barley shoot fly (Delia arambourgi) and chaffer grub (*Melolontha* sp.) and both broad leafed and grass weeds that contribute to reduced barley yields. In studies conducted at Holetta, scald and net blotch may reduce grain yield by 21-67% and 25-34%, respectively [12]. Barley shoot fly may reduce yield by more than 56% and aphids may cause 4% to 79% [3] loss or even total crop failure.

Despite barley's long history of cultivation, traditional practices and its valuable uses, the improvements made to boost the productivity of the crop have been low. In Ethiopia, research efforts to improve the production and productivity of the crop started in the early 1950s by the former Alemaya College of Agriculture and Mechanical Arts at its branch experimental station in Debre Zeit with the evaluation of landraces and introduced nurseries. Currently, barley research is coordinated from Kulumsa Agricultural

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Research Center but the breeding work is led by Holetta Agricultural Research Center (HARC). Introduced germplasms have been studied and evaluated at HARC, which serves as a quarantine site [14]. Every year, exotic germplasms is evaluated for desirable agronomic characters such as grain yield, lodging resistance, maturity, grain colour and plumpness and resistance to diseases (scald and net blotch) and insect pests (shoot fly and aphids). Between 1966 and 1993 over 22,000 and between 1994 and 2001, about 6,400 entries of introduced germplasms were evaluated. However, most of them were highly susceptible to scald, net and spot blotches, barley shoot fly and had poor plant vigor and small grains. About 6% were selected for further study [7].

In the early 1970s, the major germplasm contributors to these nurseries were the FAO Near East Regional Program, the USDA and the Arid Land Agriculture Development. Since the mid-1970s, ICARDA has also been a principal contributor of germplasm. In earlier days, some germplasms were also received from Brazil, Columbia, the former Czechslovakia, Egypt, India, Kenya, Peru, Sweden and the former Republic of Yugoslavia [14]. From these efforts, one hulled-barley variety, AHOR 880/61 was released and some other elite lines are being used as sources of genes for desirable agronomic traits such as grain quality and stiff straw and for disease and insect pest resistance in the national crossing program. According to [25], the total number of barley germplasm holdings in the Institute of Biodiversity Conservation (IBC) in 2001 was 14,592 and their characterization is under way [7].

Similarly, some barley materials developed for arid and semi-arid areas and were introduced to Ethiopia by Tigray agricultural research institutein 2007 cropping season from ICARDA. However, apart from some observations made on these germplasm by the Mekele Agricultural Research Center on some of the major traits including adaptability, there has been little systematic evaluation work. Phenotypic evaluation of germplasm for different environment is the initial step for variety development andamajor indicator for Successful breeding programs.Therefore, the objective of this study was to evaluate the performance of barley germplasm for yield and its related traits.

MATERIAL AND METHODS

Description of the Study Sites: The experiment was conducted at three locations of Tigray region, namely Atsbi, Ofla and Quiha where barley grows most with an erratic rainfall where heavy rain alternate with dry periods resulting in alternating floods and dry periods. The region receives the least rainfall compared to other parts of Ethiopia. The average annual rainfall for the period from 1961 to 1987 was 571 mm, which was 38% less than the national average (921mm) for the same period [17-24]. The mean annual rainfall ranges from 980 mm on the Central plateau to 450 mm on the Northeastern escarpments of the region [21]. The annual rainfall shows a high degree of variation ranging from 20% in the Western to 49% in the Eastern parts of Tigray [10]. The map of experimental sites is given in Fig. 1 and the different characteristics of each location are presented in Table 1.

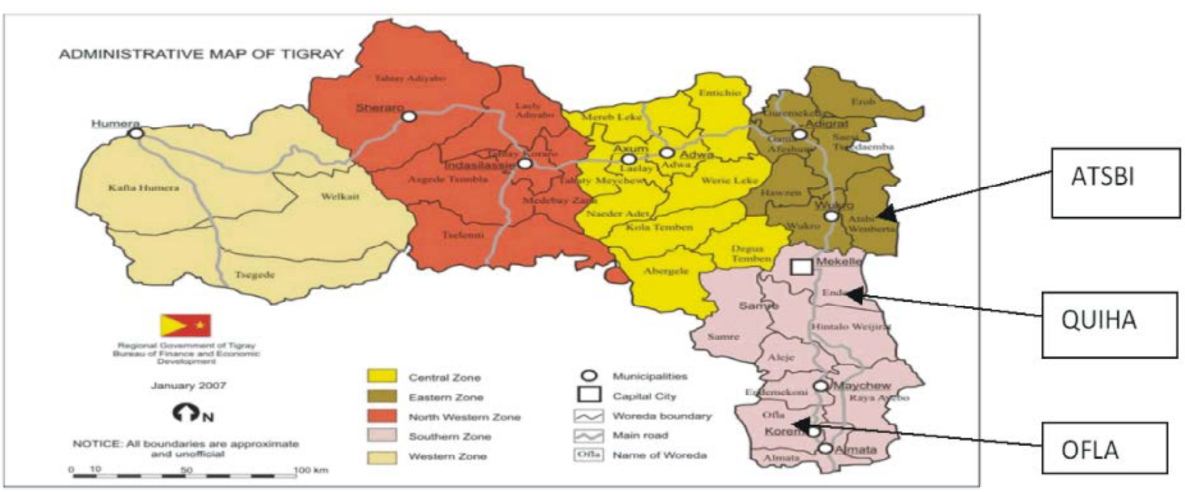

Fig. 1: Map of Tigray regional state showing experimental environments.
Source: Regional Government of Tigray Bureau of Finance and Economic development (2007).

Table 1: Different characteristics of locations

Testing location	AEZ	Altitude (m.a.s.l)	Location		Annual Rainfall (mm)	Annual Temperature		Soil Type	Soil pH
			Latitude	Longitude		Min.	Max.		
Atsbi	SM2e	2630	13°52'N	39°44'E	500 - 600	15°c	35°c	Sandy loam	6.1
Quiha	Not available	2247	13°30'N	39°29'E	812.4	15.4°c	20.4°c	Clay loam	6.7
Ofla	SM2a	2539	12°30'N	39°31'E	450 - 800	6°c	32° c	Clay loam	5.2

Source: [1, 2].

Experimental Materials: A total of 64 barley genotypes from ICARDA and one local check (Saesea) were considered in this study.

Experimental Design, Management and Season: The experiments were conducted the main cropping season. The trials were laid out in 8x8 Simple Lattice design with two replications at three locations. Each plot was 2m long and 0.8m wide, which consisted of four rows with a spacing of 20 cm between rows. The middle two rows were used for data collection. Planting was done by hand drilling using a seed rate of 80kg/ha for each treatment. All other management practices such as weeding and fertilization (urea 50kg/ha and DAP 100kg/ha) were uniformly applied to all plots.

Data Collected: Data were collected for quantitative characters like plant height, spike length and number of kernels spike^{-1} were recorded on plant basis by randomly selecting 10 plants from each plot. Number of productive tillers/m^2 was recorded by counting the whole second row and then converted into 1m^2 area, whereas days for heading, days for maturity, 1000-kernel weight, biological yield, grain yield and germination test were estimated on plot basis (Table 3). The germination test was done by soaking 100 seeds of each genotype in water for 12 hours. Then the seeds were planted using top-dressing method on filter paper and two batches of fifty seeds of each genotype were germinated per germination box, which were kept under its plastic cover to reduce evaporation. The germination boxes were placed on the laboratory bench at room temperature of 20°c (± 0.5) and were watered every other day. Finally, evaluation for the germination test was done on the seventh day from sowing day. A seed was considered to have germinated if the radicle exceeded 2mm in length [17].

Statistical Analysis

Analysis of Variance (ANOVA): The data collected for each quantitative trait were subjected to analysis of variance (ANOVA) for simple lattice design. Analysis of variance was done using Proc lattice and Proc GLM procedures of SAS version 9.2, [20] after testing the ANOVA assumptions. Before pooling the data across environments, test of heterogeneity for error of variance was done. The difference between treatment means was compared using DMRT at 5% probability levels.

The model for lattice design is:

$$Yil(j) = \mu + ti + rj + (b \mid r)l(j) + eil(j)$$

Where,

$Y_{il(j)}$ is the observation of the treatment i ($i = 1,\dots, v = k^2$), in the block l ($l = 1,\dots, k$) of the replication j ($j = 1,\dots, m$); μ is a constant common to all observations; t_i is the effect of the treatment i;r_j is the effect of the replication j;$(b|r)_{l(j)}$ is the effect of the block l of the replication j;$e_{il(j)}$ is the error associated to the observation $Y_{il(j)}$, where $e_{il(j)} \sim N(0, s)$, independent.

RESULT AND DISCUSSION

Analysis of Variance: The analysis of variance for different characters at Atsbi, Ofla and Quiha locations are presented in Table2, 3and 4, respectively. There was very highly significant differences (P< 0.001) among genotypes for all characters considered in all environments except for 1000-kernel weight at Quiha which was significant (p< 0.05) and plant height was non-significant at both Atsbi and Ofla locations.

The relative efficiency of the two designs showed that for most characters simple lattice design is not more efficient than complete randomized block design (RCBD) (Table 2, 3 and 4). Results obtained from test of homogeneity for error of variance showed the computed Chi-square test (x^2) value exceeds the corresponding tabular (x^2) value at 5% and 1% level of significance for all traits. Therefore, the hypothesis of homogeneous variance is rejected [13]. Therefore, the analysis of variance and other statistical analysis were run for the three locations separate.

Table 2: Analysis of variance for the 11 characters of barley genotypes tested at Atsbi, using Simple Lattice Design

	Mean square							Efficiency
Source of variance	Replications	Treatments Unadj.	Adj.	Blocks within Reps (adj)	Error Intrablock	RCBD	R^2 (%)	Relative to RCBD (%)
Degrees of freedom	1	63	63	14	49	63		
Plant Height	50.63	91.38	83.12	50.71	65.07	61.88	67.15	95.10
Days to maturity	5.28	37.71	33.86**	4.65	5.32	5.17	90.37	97.19
Days to heading	8.51	38.29	32.58**	2.15	2.26	2.24	95.67	98.90
1000-Kernel Weight	29.07	73.54	68.60**	24.68	13.78	16.20	88.12	107.07
Productive tillers /m^2	7225.52	13792.00	11549.63**	3706.4	3310.38	3398.38	85.12	100.28
Spike Length	0.02	1.85	1.53**	0.20	0.24	0.23	90.94	95.63
Kernels per Spike	2.65	142.75	117.68**	4.01	4.98	4.76	97.38	95.65
Biological Yield	214.92	721.55	575.48**	385.70	243.14	274.82	81.09	104.45
Grain Yield	69.40	265.33	203.50**	90.95	69.67	77.40	84.10	101.51
Harvest Index	0.002	0.009	0.0064**	0.0008	0.0012	0.001	90.33	91.59
Germination Test	6.13	61.93	51.18**	6.27	10.00	9.17	89.07	91.70

*, ** Indicates significance at 0.05 and 0.01 probability levels, respectively.

Table 3: Analysis of variance for the 11 characters of barley genotypes tested at Ofla, using Simple Lattice Design

	Mean square							Efficiency
Source of variance	Replications	Treatments Unadj.	Adj.	Blocks within Reps (adj)	Error Intrablock	RCBD	R^2 (%)	Relative to RCBD (%)
Degrees of freedom	1	63	63	14	49	63		
Plant Height	25.56	124.14	110.61	89.39	92.57	91.87	66.73	99.24
Days to maturity	13.13	26.61	25.86**	7.72	4.15	4.94	89.84	108.04
Days to heading	10.70	20.78	20.23**	8.01	5.89	6.36	83.22	101.99
1000-Kernel Weight	3.65	9.74	8.24**	1.18	1.42	1.37	90.08	96.16
Productive tillers /m^2	101.09	11582.00	9671.34**	2162.09	1878.65	1941.64	89.20	100.43
Spike Length	0.55*	1.82	1.55**	0.06	0.092	0.086	96.24	92.95
Kernels per Spike	23.38	201.84	173.61**	5.21	5.97	5.80	97.77	97.16
Biological Yield	1.59	644.96	569.94**	250.73	237.92	240.76	79.11	100.06
Grain Yield	17.94	148.37	137.14**	65.43	56.89	58.79	78.67	100.42
Harvest Index	0.0024*	0.0052	0.0044**	0.0004	0.0005	0.0004	93.79	96.17
Germination Test	1.13	154.96	132.73**	8.66	7.71	7.91	96.32	100.30

*, ** Indicates significance at 0.05 and 0.01 probability levels, respectively.

Table 4: Analysis of variance of the 11 characters of barley genotypes tested at Quiha, using Simple Lattice Design

	Mean square							Efficiency
Source of variance	Replications	Treatments Unadj.	Adj.	Blocks within Reps (adj)	Error Intrablock	RCBD	R^2 (%)	Relative to RCBD (%)
Degrees of freedom	1	63	63	14	49	63		
Plant Height	157.53*	90.87	74.89**	16.52	16.25	16.3133	88.47	100.01
Days to maturity	0.01	32.09	24.80**	1.12	1.02	1.0396	97.62	100.22
Days to heading	0.01	26.41	21.27**	1.02	1.47	1.3729	95.87	93.0996
1000-Kernel Weight	2.08	59.46	59.79*	22.79	35.74	32.8652	69.90	91.9488
Productive tillers /m^2	775.20	3659.18	3244.83**	542.29	473.37	488.69	91.15	100.4
Spike Length	2.05*	2.22	1.74**	0.17	0.43	0.3722	87.29	86.7616
Kernels per Spike	66.85*	113.82	101.57**	7.92	7.32	7.4506	95.35	100.14
Biological Yield	72.50	164.78	153.67**	11.21	27.21	23.65	88.84	86.91
Grain Yield	3.65	34.99	33.16**	2.43	3.94	3.60	92.08	91.49
Harvest Index	0.001	0.015	0.014**	0.001	0.0012	0.0011	94.28	96.29
Germination Test	1.13	170.86	162.45**	7.16	5.52	5.90	97.57	101.43

*, ** Indicates significance at 0.05 and 0.01 probability levels, respectively.

Table 5: Range and mean of barley genotypes evaluated at Atsbi, Ofla and Quiha.

	Atsbi		Quiha		Ofla	
Characters	Range	Mean ± S.E Mean	Range	Mean ±S.E Mean	Range	Mean ± S.E Mean
Plant height	40.3 - 84.9	62.21 ± 0.44	40.8-91.6	71.51 ± 0.528	29.3-61.6	44.96 ± 0.221
Days to maturity	69 – 94	79.17 ± 0.13	86-104	95.70 ± 0.112	68-82	74.99 ± 0.055
Days to heading	38 – 65	48.54 ± 0.08	51-68	62.05 ± 0.133	38-53	45.15 ± 0.067
1000-kernel weight	15.2 - 54.4	40.84 ± 0.20	13.6-24.8	19.95 ± 0.066	14.8-54.8	32.03 ± 0.328
Productive tillers/m^2	26.25 – 481.25	253.16 ± 3.16	16.25-407.5	163.23 ± 2.380	16.25-212.5	81.56 ± 1.195
Spike length	3.8 - 8.8	5.81 ± 0.03	3.1-8.5	5.82 ± 0.017	2.5-8.3	5.45 ± 0.036
Kernels per spike	15.3 - 48.1	25.85 ± 0.12	15.3-51	26.30 ± 0.134	13.9-43.4	24.70 ± 0.149
Biological yield	24.70 – 131.84	77.33 ± 85.61	19.76-122.36	78.60 ± 84.681	10.14-67.83	32.05 ± 28.640
Grain yield	8.51 – 66.65	36.02 ± 45.83	5.44 -56.09	35.87 ± 41.414	1.63-29.75	9.58 ± 10.894
Harvest index	0.278 - 0.565	0.46 ± 0.0015	0.28-0.57	0.46 ± 0.001	0.081-0.514	0.29 ± 0.002
Germination test	66 – 100	92.95 ± 0.17	66-100	88.70 ± 0.152	64-100	92.97 ± 0.129

S.E Mean= Standard error of the mean

Range and Mean of Different Characteristics: Estimated range, mean and standard error of the mean for the 11 characters are presented in Tables 5 and the mean performanceof 64 barley genotypes is presented in Appendices 1, 2 and 3 for Atsbi, Ofla and Quiha, respectively. There is a wide range of unevennessobtained from the characters tested in different locations. The main season was known by its early halted rainfall across Ethiopiaas well as Tigray. Therefore, it is an ideal season to test the introduced drought tolerant barley genotypes.

Grain Yield: There was a very highly significant difference ($p<0.001$) among genotypes for grain yield across location. At Atsbi environment, grain yield ranged from 8.51 to 66.65 qt/ha, at Ofla from 5.44 to 56.09 qt/ha and at Quiha from 1.63 to 21.55 qt/ha (Tables 5). It was observed that the overall mean for grain yield was the lowest (9.58 qt/ha) at Quiha environment, whereas Ofla seems to be ideal for cultivation of barley as the overall mean grain yield of the location was 36.13 qt/ha which is the highest among the three locations. This may be attributed to the lower rain shower at Quiha especially starting from heading towards grain filling period in the season as compared to the two locations. In addition, at Atsbi the overall mean production was 36.02 qt/ha, resulted from enough amount of moisture during the critical time (starting from heading towards grain filling period) in the mid of August [25].

Yield Related Traits: According to [26], a major feature of barley adaptation to low rainfall and high temperature is its early emergence. Early emergence of ear is a desirable agronomic trait which makes it early enough to ensure that pollination and grain filling take place before heat and moisture stresses become too severe. Using this point as a benchmark, genotypes with average days to heading was observed lowest (45 days) at Quiha, whereas highest (62 days) at Ofla. Similarly, clear differences among genotypes for days to maturity were observed, that is the effect of environments on the genotypes was higher. If we compare the genotypes at Quiha and Ofla, the genotypes were observed to mature at early (75 days) at Quiha resulted in less grain and biomass yield. This was because of moisture stress and high temperature at Quiha, while most genotypes matured late with an average of 95 days at Ofla. This was due to the relatively low temperature and better moisture in the growing season at Ofla.

Plants with short straw generally lodge less than tall plants. The great differences between the minimum and maximum values of plant height showed significant variation in the level of this character between individual genotypes across locations. The average plant height was shortest (44.96 cm) at Quiha, where the development of plants was inhibited by relatively low rainfall and the tallest (71.51cm) in wet conditions of Ofla. The variation of average results of plant height (44.96 - 71.51cm) in the testing sites indicates the heterogeneity of the testing sites on the level of this character. This result was in harmony with reports of [22] where, the average plant height was shortest in the testing year 2002 when the development of plants was inhibited by heavy drought and tallest in wet conditions in 2000 [26].

There were great difference between minimum and maximum values for the trait number of productive tillers/m^2 with a range of 26 – 481 at Atsbi,16 - 408 at Ofla and 16-213 at Quiha environments, respectively.

It was clearly observed that, the lowest maximum number of productive tiller/m^2 was obtained from Quiha. This is due to number of productive tillers/m^2 is influenced by the density of stand and the genetics of the cultivar, as well as environmental factors. In this experiment, the same genotypes with the same seed rate per plot was applied each location. Therefore, this low number of productive tillers/m^2 was resulted from the environmental factor, which is the amount of rainfall in Quiha case. In agreement with this, at common seeding rates, a single plant usually develops from one to five stems but under thin stands and favorable conditions it may have several times that number [19, 8]. Besides, [15] reported that, the magnitude of the difference in tillering was more affected by the environment.

Spike length is a character of considerable importance, as the larger spike is likely to produce more grains and eventually higher yield. Spike length ranges from 3.8 to 8.8 cm, 3.1 - 8.5 cm and 2.5 - 8.3 cm at Atsbi, Ofla and Quiha sites respectively. This variability was resulted from morphological character of the genotypes. That is, two-row barley had a relatively long spike as compared to the six-row barley. This is in consistence with this result reported by [11] that wheat genotypes retaining larger spikes under moisture stress are likely to be more productive under stress environment. Moreover [27] indicated that, six-rowed barley had shorter spike length than the two-rowed barley.

Similarly, there is a wide range of changeability in number of kernels/spike that was resulted from variability between genotypes. That is, for genotypes having equal spike length most of the two-row barley produced a number of kernels that ranges from the minimum to the mean value, while the later ranged from the mean value to the maximum number. Furthermore, two-row barley had good grain size as compared to six-row barley at Quiha, while the reverse is true at Ofla. This was resulted from early maturing nature of the two-row, while most of the six-row types left with shrieked seed. This is in agreement with the result obtained by [15] thatsix-rowed barley consistently had more grains per spike, with a lower average grain weight.

Germination test was made to identify and select genotypes with better germination under increasing drought stress levels. The range for germination test was between 66 – 100% both at Atsbi and Ofla while at Quiha it ranges between 64 -100%. The mean value for germination test was 93% at both Quiha and Atsbi environment, whereas 89 % at Ofla location. The mean value showed that except for few genotypes, most of them had early emergence and this earliness is a mechanism of drought escaping and better adaptability to harsh environments in crop plants.

CONCLUSION

The result showed that there was a very highly significant difference ($P<0.001$) among genotypes for all characters considered in all environments except for 1000-kernel weight which is significant ($P<0.05$) at Quiha and plant height was non-significant both at Atsbi and Ofla.

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