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Research Article

Evaluation of exotic barley genotypes for adaptation, yield and its component traits under irrigated conditions of North West India

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Abstract

Field evaluation of 24 exotic barley (*Hordeum vulgare* L.) genotypes for adaptation, yield and its component traits along with two national checks BH946 (six-row) and DWRUB52 (two-row) was carried out at Punjab Agricultural University, Ludhiana, Punjab, India under irrigated conditions over two crop seasons 2014-15 and 2015-16. Temperature and precipitation prevailing during two crop seasons significantly influenced all the parameters except grains per spike, ear length and 1000-grain weight. High rainfall resulted in significant crop lodging (20-100% lodging) during year 2014-15 in genotypes IBYT 2, 5, 6, 11, 14, 16, 17, 19, 20, 21, 24 and check BH946 which caused significant yield reduction. High temperature during 2015-16 caused significant reduction in phenological stages such as days to heading, days to maturity in all genotypes. Grain filling period, which is major factor responsible for bold grains, also reduced in all the genotypes except IBYT 1, 2 and 23. Two entries, IBYT 14 and IBYT 21 were significantly earlier in heading than the best check DWRUB52 (94.3 days) by 5 days and 3 days, respectively. Exotic genotype IBYT4 is also a short-stature (96.3 cm height) genotypes, performed well for tiller number per meter, grains per spike and ear length. Genotype IBYT 18 possessed desirable values for grains per spike and 1000-grain weight. All exotic genotypes produced significantly lower grain yield (2.1-4.3 t/ha) than check DWRUB52 (4.9 t/ha). Six exotic genotypes (IBYT 18, IBYT 5, IBYT 7, IBYT 20, IBYT 21 and IBYT 23) with grain yield at par with check BH946 (3.9 t/ha) were identified and may be used in breeding programme for widening the genetic base of six rowed barley germplasm.

Keywords: Barley, grain yield, exotic, adaptation, yield components.

1. Introduction

Barley (*Hordeum vulgare*) is considered as fourth important cereal after maize, wheat and rice with 142.37 million metric tons production worldwide during 2017-18 (https://www.statista.com). In India, it occupies 680 thousand ha area with 1.79 million tons production (Kharub *et al.*, 2018). Major barley growing areas in India are Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab, Himachal Pradesh, Uttarakhand, Bihar and Jammu & Kashmir. Barley is known as king of cereals because it is used for several purposes such as feed, food and malt purpose. It was important food in countries such as ancient Egypt, Mesopotamia and Greece (Ullrich, 2011), but human interest in barley has decreased with time due to preference for wheat bread. But recently, barley is becoming popular owing to its neutraceutical properties and potential health benefits produced by soluble fiber β-glucan (Behall *et al.*, 2004; Johansson *et al.*, 2013). Barley β-glucans play an important role in lowering cholesterol level, improving lipid metabolism, reducing glycemic index and the risk of colorectal cancer (Granfeldt *et al.*, 1994; Delaney *et al.*, 2003; Behall *et al.*, 2004; Brennan and Cleary, 2005; Keenan *et al.*, 2007; Johansson *et al.*, 2013).

Besides food and nutritional value, barley is also used widely in distillation and brewing industry for preparing malt and malt based products like beer, whisky, malt vinegar, malted shakes, flavored drinks such as horlicks, ovaltine and milo baked products. Barley grain is being used as feed for livestock such as dairy cattles, buffalos, poultry, horses and pigs etc. For feed purpose, high crude protein barley is required. In comparison with corn, barley has more protein, especially rich in amino acids methionine, cysteine, lysine and tryptophan, thus highlighting the potential contribution of barley for meeting the protein requirements of growing ruminants. Modern plant breeding methods such as pure line breeding has led to the narrow genetic base of barley germplasm. Therefore, use of exotic and wild germplasm of barley is emphasized to widen the genetic base of cultivated barley for significant improvement in grain yield and quality attributes. Success of exotic crop material depends largely on adaptation of a particular crop. Crop plants adapt themselves when introduced in different environments for their survival. Among these, barley is most adaptive cereal when grown under heat, drought, poor and salt affected soils. It is well adapted to harsh environments (Dai *et al.*, 2012; Van- Oosterom *et al.*, 1992; Coventry *et al.*, 2004; Eglinton *et al.*, 2001) indicating the potential use of exotic barley germplasm for breeding, especially against abiotic stresses such as cold, heat and drought. Most important traits for adaptation of barley are flowering time and photoperiod requirements. In barley, the major genes underlying flowering time are vernalization genes *viz.*, *VRNH1*, *VRNH2*, *VRNH3* (Laurie *et al.*, 1994; Yan *et al.*, 2004; Cockram *et al.*, 2007; Trevaskis 2010; Casas *et al.*, 2011) and for day length requirements, PPDH1 and PPDH2 (Turner *et al.*, 2005; Casao *et al.*, 2011) genes are important. Early flowering promotes adaptation of introduced barley material where growing season is short due to heat stress or drought stress. An example of early flowering and short-season adaptation in a landrace barley from the Qinghai-Tibetan Plateau is the loss-of-function mutations at the circadian clock gene *EARLY MATURITY 8 (EAM8)* which promote early flowering in a Tibetan barley landrace Lalu (Xia *et al.*, 2017). At Punjab Agricultural University (PAU), Ludhiana, under ICARDA-BIGMP project, we had received exotic barley genotypes from ICARDA, Morocco during Rabi season 2014-2015. The genetic potential of these barley genotypes for adaptation, yield and its component traits was not known in our conditions at PAU, Ludhiana. So, the objective of our study was to evaluate ICARDA barley genotypes for adaptation, grain yield and its component traits to irrigated conditions in Punjab.

2. Materials and methods

A set of 24 hulled barley genotypes introduced from ICARDA, Morocco as International barley yield trials-high input conditions (IBYT-HI) and two national checks BH946 (six-row) and DWRUB52 (two-row) were sown in the field in randomized complete block design with 2 replications in plot size of 2.5 m row length, 6 rows and row to row distance of 30 cm during winter (October-April) of 2014-15 and 2015-2016. Experiment was carried out at Punjab Agricultural University, Ludhiana, Punjab, India (Latitude: 30^{0}56'N; Longitude:72^{0}52'E; Altitude: 246m) under irrigated conditions. For sowing, approximately 35 g seeds per genotype per plot were sown. First irrigation was applied 21 days after sowing, 2nd and 3rd irrigations were applied after interval of 3-4 weeks depending on precipitation during particular crop season. For fertilization, 60 kg nitrogen per hectare and 40 kg phosphorous per hectare were applied at time of sowing. Manual hoeing was performed at seedling stage and tillering stage. Days to heading was recorded from the number of days taken from the date of sowing to 75 per cent spike emergence per plot for each genotype. Days to maturity were recorded from the number of days taken from the date of sowing to 75 per cent maturity of plants for each genotype. Grain filling period was calculated by deducting days to heading from days to maturity. For measuring plant height, height of plant from the ground level to the tip of the main spike excluding awns was measured at the time of maturity for five random plants for each genotype and average plant height was worked out. For tiller number per meter, the number of effective tillers in one-meter row length was counted. Spike length of five spikes from each plot was measured and averaged. Grains per spike were worked out as average number of grains per five spikes. Thousand grain weight was estimated as weight of 1000 grains. For biomass, all plants from each plot were harvested above the ground level and weight of total produce was recorded after harvesting. Similarly, for grain yield, weight of dry grains for each genotype was recorded after threshing the harvested plot separately. Harvest index was calculated by dividing grain yield with biomass. Data were analyzed using software CPCS1 developed by Punjab Agricultural University, Ludhiana for analysis of variance in RBD design.

3. Result and discussion

Analysis of variance for adaptation traits, yield and agronomic traits is presented in Table 1. Years had high significant effect on days to heading, days to maturity, grain filling period, plant height, tiller number, biomass,

Table 1: Analysis of variance for various morphological traits in hulled barley pooled over 2 years (2014-15 and 2015-16)

Source of Variation	d.f.	Mean Square										
		Days to heading	Days to maturity	Grain filling period	Plant Height	Tiller Number	Grains per spike	Ear Length	1000 grain weight	Biomass	Grain Yield	Harvest Index
Years (Y)	1	1921.25**	3792.13**	984.61**	396.25*	162**	71.12	0.036	3.03	98863.25**	1513.48**	0.58**
Genotypes (G)	25	70.76**	18.85**	38.84**	98.46	578.51**	664.83**	7.51**	49.91**	1088.53**	188.48**	0.0061**
G x Y Interaction	25	7.20**	6.02**	31.70**	72.03	419.48**	51.64	0.1	15.95	401.83**	71.43**	0.0036**
Error	50	2.64	1.89	2.45	57.45	98.69	31.34	0.71	10.85	100.69	9.5	0.000

Figures with * and ** are significant at 5% and 1% level of significance, respectively

grain yield and harvest index except grains per spike, ear length and 1000-grain weight. This means these traits expressed differentially in the two crop seasons 2014-15 and 2015-16. All the genotypes were earlier in heading and maturity in crop season 2015-16 as compare to crop season 2014-15 (data not given). Grain filling period was also reduced drastically in all the genotypes except IBYT 1, IBYT 2 and IBYT 23. This acceleration in phenological stages was due to high temperature prevailing from January-April, 2015-16 (Table 2).

Table 2: Mean monthly air temperature and rainfall data at Ludhiana over two crop seasons

Month	Rabi 2014-15			Rabi 2015-16		
	Air Temperature (°C)		Total Rainfall (mm)	Air Temperature (°C)		Total Rainfall (mm)
	Max.	Min.		Max	Min	
October	31.2	18.9	12.9	31.3	19	16.4
November	26.9	10.9	0	26.9	12.6	0
December	17.8	7	42.2	21.3	7.3	1.7
January	15.6	7.1	24.6	17.2	7.4	19.4
February	22.2	10.5	38.6	23	9	8.8
March	25.5	13.1	84.6	28	14.6	41.15
April	32.6	19.5	29.4	36.6	19.6	3
Total Rainfall (mm)			232.3	Total rainfall (mm)		90.45

High temperature during January-February, 2015-16 caused significant reduction in days to heading while high temperature during March-April, 2015-16 caused significant reduction in grain filling period and days to maturity. These results are in agreement with studies conducted in wheat by Al-khatib and Paulsen (1990), Zhong and Rajaram (1994), Ishag and Mohamed (1996) and Kaur *et al.* (2009). During *rabi* season 2014-15, total rainfall was 232.3mm which was substantially higher than *rabi* 2015-16 (90.45mm) (Table2). High rainfall resulted significant crop lodging (20-100%) in genotypes IBYT 2, 5, 6, 11, 14, 16, 17, 19, 20, 21, 24 and check BH946 during year 2014-15 (data not given). Klink *et al.* (2014) also reported a significant impact of high temperature and precipitation on barley and oat yield over the past 33 years (1980-2012) in Minnesota and surrounding regions. Test of significance for genotypes were highly significant for all the parameters tested except for plant height. Therefore, these exotic genotypes possess huge genetic variation for grain yield and other agronomic traits which can be used for improvement of indigenous barley cultivars. Previous studies on evaluation of exotic barley germplasm indicated that significant variations existed for many of these traits like days to heading, days to maturity, grain filling period, plant height, ear length, tiller number, thousand grain weight and grain yield (Kaur *et al.*, 2016). Kumar *et al.*, (2017) reported high diversity for tiller number per plant, earhead per plant, grain yield per plant and moderate diversity for length of earhead, spikelets per earhead, grains per earhead and 1000 seed weight in ICARDA genotypes. But plant height and days to maturity had least diversity. Studies on evaluation of barley landraces in Ethopia indicated that significant variations existed for traits like plant height, days to heading and thousand grain weight (Derbew *et al.*, 2013, Alemayehu and Parlevliet, 1997) and for days to maturity, spike length, seeds per spike, heads per square meter and grain yield per spike (Assefa, 2003). Lakew *et al*, (1997) also reported large amount of variation between barley populations for days to heading, maturity and plant height in Ethopian landraces. For genotype and years interaction, the analysis of variance was found to be highly significant for days to heading, days to maturity, grain filling period, tiller number, biomass, grain yield and harvest index. Rodriguez *et al.* (2008) also found significant genotype by environment interactions for grain yield, degree days to booting, degree days to maturity, number of kernel m-2, number of spikes m-2, number of kernels per spike, thousand kernels weight, plant height and lodging score. In contrast to this study, our results showed that GxY interaction was non-significant for plant height, grains per spike, ear length and 1000-grain weight. Therefore, these traits are less affected by varied temperature and precipitation prevailing during both crop seasons and these traits remained more stable over two crop years in exotic barley genotypes. Minimum, maximum and pooled values over both crop seasons were presented in

Table 3. Heading and maturity dates are important for adaptation of exotic germplasm when introduced in the different growing conditions. The tested material in our study had been developed at ICARDA, Morocco, which was geographically different from conditions prevailing at Ludhiana station, India. For days to heading, exotic barley genotypes ranged from 88.8-107.5 days with a mean value of 97.3 days (Table 3). IBYT genotypes fall in three groups differentiating significantly early heading, at par and late heading when compared to check DWRUB52 and BH946. Two entries, IBYT 14 and IBYT 21 were significantly earlier in heading than the best check DWRUB52 (94.3 days) by 5 days and 3 days, respectively. Genotypes with early heading are desirable for adaptation to regions where short crop seasons prevails due to heat and drought stress (Casas *et al.*, 2011; Boden *et al.*, 2014). For days to maturity, tested barley genotypes ranged from 131.3-140.0 days with a mean value of 136.1 days falling in early, at par and late maturity group with respect to DWRUB52. But with respect to check BH946, IBYT genotypes fall in early and at par group and no entry was significantly late in maturity than this check. For grain

Table 3: Performance of exotic IBYT barley genotypes for adaptation traits pooled over 2 years (2014-15 and 2015-16)

Entry	Row type	Days to heading (days)	Days to maturity (days)	Grain filling period (days)	Plant Height (cm)	Tiller No.	Grains per spike	Ear Length (cm)	1000 -Grain weight (gm)	Biomass (t/ha)	Grain yield (t/ha)	Harvest index
IBYT 1	6	97.5	136.3	39.5	96.5	90.3	67	9.5	32.7	14.8	3.3	0.22
IBYT 2	6	101.5	137.5	39.5	96	101.3	75	9.2	37.1	14.5	2.9	0.2
IBYT 3	6	96.8	136.3	41.3	101.3	111.5	72	8.8	34.7	15.3	2.2	0.16
IBYT 4	6	93	133.3	40.8	96.3	116	87	12.7	29.6	15.3	2.6	0.19
IBYT 5	6	93	136.5	39.3	93.9	134.8	75	8	37	16.1	4.3	0.27
IBYT 6	6	92	134	40.8	93.5	89.5	81	9.4	35.8	13.4	3.4	0.26
IBYT 7	6	97	137.8	36.5	99.7	103.8	68	9.1	38	15.7	3.7	0.24
IBYT 8	6	103.3	140	31.3	93.5	106.5	68	6.8	29.2	15.3	3.2	0.23
IBYT 9	6	100.8	135.3	35.8	93.6	92.8	71	8.6	36	14.9	2.9	0.21
IBYT 10	2	96.3	133	36.3	94.4	116.5	33	9.4	40.8	12.8	2.7	0.25
IBYT 11	6	93	134	35.3	98.3	103	81	10.1	35.4	12	2.2	0.21
IBYT 12	6	98.3	137	38	101.8	86.8	78	11.3	34.6	14.9	3.1	0.22
IBYT 13	6	98.5	137.5	38.8	101.8	96.8	80	11.2	32.9	13.5	2.9	0.24
IBYT 14	6	88.8	133.5	42.8	94	100.8	77	10.9	34.1	10.4	2.1	0.24
IBYT 15	6	99.3	137.5	32.5	103.9	103.5	84	10.6	33.7	16.2	3.4	0.23
IBYT 16	6	101.3	138.3	37.8	99.3	120	69	7.5	31.6	17.1	3.5	0.21
IBYT 17	6	99.5	137	37.5	103.9	100.5	76	9.9	40.7	15.7	3.2	0.22
IBYT 18	6	97.8	135.8	35.3	103	91	75	8.2	40.2	16.3	4.3	0.28
IBYT 19	6	97.8	136.5	39.5	110.2	102.5	72	11.2	42.3	14.8	2.2	0.17
IBYT 20	6	95.5	134.3	37.5	100	106.8	79	9.3	35.7	15.5	3.6	0.25
IBYT 21	6	91	131.3	35.8	96.4	111.8	75	8.1	35.2	14.1	3.6	0.28
IBYT 22	6	102.3	137	34.5	100.7	89.3	73	9	33.9	16	3.5	0.23
IBYT 23	6	107.5	139.8	32.3	103.8	107.5	64	7.9	36.2	15.9	3.5	0.26
IBYT 24	6	94.8	134	38.8	96.1	95	81	8.7	35.5	15	3.3	0.24
BH946	6	99.5	138.5	34.5	104.5	99.8	75	8.7	34.8	18.7	3.9	0.22
DWRUB52	2	94.3	137.5	43.3	86.6	128	31	8.1	43.6	13.9	4.9	0.36
Minimum		88.8	131.3	31.3	86.6	86.8	31	6.8	29.2	10.4	2.1	0.16
Maximum		107.5	140	43.3	110.2	134.8	87	12.7	43.6	18.7	4.9	0.36
Mean		97.3	136.1	37.5	98.6	104.1	72	9.3	35.8	14.9	3.2	0.23
LSD 5%		2.3	2	2.2	NS	14.1	8	1.2	4.7	1.4	0.4	0.03

filling period, values ranged from 31.3-43.3 days with a mean value of 37.5 days. The highest value of 43.3 days was observed in check DWRUB52 and two entries IBYT 14 (42.8 days) and IBYT 3 (41.3 days) were at par to DWRUB52 (43.3 days). Genotype IBYT14 was having early heading and more grain filling period and found to possess good adaptation to climatic condition prevailing in Punjab. For plant height, we observed no critical difference among the tested entries. For biomass, grain yield and harvest index, range varied from 10.4-18.7t/ha, 2.1-4.9 t/ha and 0.16-0.36, respectively (Table 3). For grain yield, check DWRUB52 (4.9 t/ha) had the maximum grain yield among the tested entries and no entry was even at par to it whereas six entries, IBYT 18 (4.3 t/ha), IBYT 5 (4.3 t/ha), IBYT 7 (3.7 t/ha), IBYT 20 (3.6 t/ha), IBYT 21 (3.6 t/ha), IBYT 16 (3.5 t/ha), IBYT 22 (3.5 t/ha) and IBYT 23 (3.5 t/ha) were at par to BH946 (3.9 t/ha). Two exotic entries *viz.*, IBYT 14 (10.4 t/ha) and IBYT 11 (12.0

t/ha) had significantly less biomass and ten entries (IBYT 1, 2, 6, 9, 10, 12, 13, 19, 21 and 24) were at par to best check DWRUB52 (13.9 t/ha). Thirteen entries were having significantly higher biomass than DWRUB52 (13.9 t/ha) and BH946 had the highest biomass (18.7 t/ha) among these. Most of the IBYT genotypes evaluated showed more biomass as compare to local checks used. The genotypes which had vernalization requirement or which require longer photoperiod those remain in vegetative phase for longer period and took more days for flowering and has higher biomass. These genotypes showed less adaptation to changed environment and hence low yielding. On other hand, genotypes which showed early flowering, they possess less biomass and more grain filling period, hence found to be high yielding. In our results, genotypes IBYT14 and IBYT21 were early heading and also possess low biomass, more grain filling period and good grain yields as compare to late heading genotypes. For harvest index, no entry was at par or superior to DWRUB52 (check) whereas six entries viz., IBYT 18 (0.28), IBYT 21 (0.28), IBYT 5 (0.27), IBYT 23 (0.26) and IBYT 6 (0.26) were having significantly higher harvest index than BH946, while 17 entries were at par to this check. In general, harvest index of exotic genotypes was less, as these genotypes possessed more vegetative mass as compare to Indian checks used. For yield components, such as tiller number per meter row, grains per spike, ear length and 1000-grain weight, range varied from 86.8-134.8, 31.0-87.0, 6.8-12.7 cm and 29.2-43.6g, respectively (Table 3). For tiller number, four entries, IBYT 5 (134.8), IBYT 16 (120.0), IBYT 10 (116.5) and IBYT 4 (116.0) were at par with the check DWRUB52 (128.0) and no entry had significantly higher tiller number than this check. For grains per spike, all the IBYT entries were significantly higher than the DWRUB52 (31.0) for grains per spike and only one entry, IBYT 10 (33.0) was at par to the check. This difference between IBYT entries and check was due to row type difference between tested entries and check, because check DWRUB52 was a two-row entry. In tested IBYT genotype, all entries were six-row except IBYT 10. Two entries namely, IBYT 4 (87.0) and IBYT 15 (84.0) were having significantly higher number of grains per spike, than check BH946 and twenty one entries were at par to BH946 (75.0). For ear length, IBYT 4 (12.7cm) had the highest ear length among all tested genotypes. Eight entries were having significantly higher ear length than best check BH946 (8.7cm) and 15 entries were at par. For 1000-grain weight, no entry was significantly higher than the check DWRUB52 (43.6g). Out of all the entries, four entries, IBYT 19 (42.3 g), IBYT 10 (40.8 g), IBYT 17 (40.7 g) and IBYT 18 (40.2 g) were at par to check DWRUB52.

Conclusion

Based on evaluation of exotic barley genotypes, we identified a set of promising genotypes for grain yield and other agronomic traits for use in breeding programme (Table 4). Genotype IBYT14 and IBYT21 were found to be early heading and semi-dwarf genotypes (plant height: 94.0cm, 96.4cm, respectively) and may be used in crossing programme for incorporation of earliness and dwarf traits for development of short duration semi-dwarf barley varieties. For yield components, IBYT4, which is also short-stature (96.3cm height) genotype, performed well for grains per spike and ear length. Genotype IBYT 18 possessed desirable values for grains per spike and 1000-grain weight. For grain yield genotypes viz., IBYT 18, IBYT 5, IBYT 7, IBYT 20, IBYT 21, IBYT 16, IBYT 22 and IBYT 23 were found to be promising and may be used in crossing programme for improving the six rowed barley germplasm for feed and food purpose.

Table 4: Promising IBYT entries identified for different morphological parameters

SN	Parameter	Desirable Performance	Promising entries
1	Days to heading (days)	Early	IBYT 14 (88.8 days), IBYT 21 (91.0 days)
2	Days to maturity (days)	Early	IBYT-21 (131.3 days), IBYT 10 (133.0 days), IBYT-4 (133.3 days), IBYT 14 (133.5 days), IBYT 6 (134.0 days),IBYT 11 (134.0 days), IBYT 24 (134.0 days), IBYT 20 (134.3 days), IBYT 9 (135.0 days)
3	Grain filling period (days)	High	IBYT 14 (42.8 days), IBYT 3 (41.3 days)
5	Tiller number/ meter	High	IBYT 5 (134.8), IBYT 16 (120.0), IBYT 10 (116.5) and IBYT 4 (116.0)
6	Grains per spike	High	IBYT 4 (87), IBYT 6 (81), IBYT 11 (81), IBYT 13 (80), IBYT 15 (84) and IBYT 24 (81)
7	Ear Length (cm)	High	IBYT 4 (12.7 cm)
8	1000- grain weight (g)	High	IBYT 19 (42.3 g), IBYT 10 (40.8 g), IBYT 17 (40.7 g) and IBYT 18 (40.2 g)
9	Biomass (t/ha)	Low	IBYT 14 (10.4 t/ha) and IBYT 11 (12.0 t/ha)
10	Grain Yield (t/ha) with respect to BH946	High	IBYT 18 (4.3 t/ha), IBYT 5 (4.3 t/ha), IBYT 7 (3.7 t/ha), IBYT 20 (3.6 t/ha), IBYT 21 (3.6 t/ha), IBYT 16 (3.5 t/ha), IBYT 22 (3.5 t/ha) and IBYT 23 (3.5 t/ha)
11	Harvest Index	High	IBYT 18 (0.28), IBYT 21 (0.28), IBYT 5 (0.27), IBYT 23 (0.26) and IBYT 6 (0.26)

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