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Performance and Variability Studies for Seed Quality Parameters in Barley (*Hordeum vulgare* L.)

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ABSTRACT: Fifty genotypes of barley (*Hordeum vulgare* L.) were assessed to study the performance and variability based on seed quality traits during *rabi* 2016-17 at CCS Haryana Agricultural University, Hisar. The observations were recorded for eight seed quality traits *viz*., seedling length (cm), seed density (g/cc), germination (%), seedling dry weight (mg), vigour index I, vigour index II, electrical conductivity (µS/cm/seed) and accelerated ageing at 48 and 72 hours. Genotypes significantly differed for all the traits under study indicated existence of sufficient variability in the experimental material under both environments. Nine genotypes *viz*., 2nd GSBSN-28 (2015), IBYT-HI-17, UPB 1059, BH 15-17, 2nd GSBSN-15-8, BH 14-25, 2nd GSBSN-60 (2015), DWRB 143 and IBYT-HI-20 were found significantly superior for one or more traits among 50 genotypes under timely sown while, six genotypes namely, BH 14-42, RD 2909, AZAD, 2nd GSBSN-28 (2015), IBYT-HI-18 and IBYT-HI-16 were exhibited significant superior performance under late sown environment. The estimates of phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) indicated that PCV was found greater than GCV for all the characters in both timely as well as under late sown conditions. Among all the traits, seed density had highest phenotypic and genotypic coefficient of variation under timely whereas, under late sown, accelerated ageing (72 h) showed maximum PCV and GCV. Germination (%) exhibited minimum PCV and GCV under both the environments. Moderate to high heritability coupled with high genetic advance under timely sown was observed for seedling density, accelerated ageing (72, 48 h) and electrical conductivity likewise, for accelerated ageing (72 h), seedling dry weight and vigour index I under late sown indicating the importance of these seed vigour traits in crop improvement.

Keywords: Barley, Seed quality, GCV, PCV, Heritability, Genetic advance, Performance

Acteristic and its association with field stand establishment and crop productivity has been worldwide recognized from the 1960s onward. The basic objective of vigor testing is to provide a consistent identification of differences in physiological potential among seed lots of commercial value and this represents a more sensitive parameter than the germination test. Delouche and Baskin [3] also reported the importance of testing seed performance using various seed vigour tests. There are various procedures to assess seed vigor including those that directly or indirectly evaluate seed metabolic state or identify seed tolerance to specific stress (s).

Some studies on genetic variability of barley have focused on quantitative traits [4, 5], others on analytical determination of the malting quality. However, literature regarding use of traits related to seed quality still lacks. [6] studied various seed vigour test *viz*., accelerated ageing, standard germination, electrical conductivity, seedling length, seedling dry weight and vigour indices in barley. This study has the purpose to assess the performance and presence of variability in different barley genotypes for seed quality traits. This kind of study could guide and create strategies for barley genetic breeding programs.

MATERIALS AND METHODS

The experiment was conducted at Barley Research Area of the Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar during *rabi* 2016-17 under irrigated conditions. The experimental location is situated at latitude of 29°10′N, longitude of 75°46′E and altitude of 215.2 m above sea level in subtropical region of North Western Plain Zone of India.

The experimental material was consisted of 50 barley genotypes (Table 1) comprising 33 six and 17 two rowed types. Each genotype was grown in randomized block design (RBD) with three replications under timely and late sown conditions having a plot size of 3.0 m × 0.69 m. Under timely sown condition, the experiment was

Table 1. Detail of barley genotypes used in the study

Sr. No.	Name of Genotypes	Row Type	Sr. No.	Name of Genotypes	Row Type
1	IBYT-HI-19	6	26	DWRB 101	2
2	IBYT-HI-13	6	27	MGL 105	6
3	IBYT-HI-17	2	28	MGL-117	6
4	IBYT-HI-16	6	29	IBON-HI-1 (2015-16)	6
5	IBYT-HI-18	6	30	IBON-HI-3 (2015-16)	2
6	IBYT-HI-23	2	31	IBON-HI-13 (2015-16)	6
7	IBYT-HI-15	6	32	IBON-HI-37 (2015-16)	6
8	IBYT-HI-20	6	33	IBON-HI-67 (2015-16)	6
9	BH 959	6	34	BH 902	6
10	DWR 123	2	35	2nd GSBSN-15-8	6
11	DWR 137	6	36	INBON-15-16	6
12	MBGSN 145	2	37	INBON-15-22	6
13	RD 2904	2	38	2nd GSBSN-15-35	2
14	RD 2909	6	39	AZAD	6
15	UPB 1059	6	40	DWRB 143	2
16	HUB 242	6	41	BH 13-20	2
17	2nd GSBSN-28 (2015)	6	42	BH 13-22	6
18	2nd GSBYT-23 (2015)	6	43	BH 13-26	2
19	K 560	6	44	BH 14-25	2
20	JB 481	6	45	BH 14-42	6
21	2nd GSBSN-60 (2015)	6	46	BH 15-17	2
22	2nd GSBYT-02 (2015)	2	47	BH 15-30	6
23	MGL-58	6	48	BH 946	6
24	MGL-62	2	49	BH 885	2
25	MGL-64	6	50	DWRUB 52	2

planted on 15th November, 2016 and on 14th December, 2016 under late sown condition.

The vigour potential of these 50 genotypes was assessed by recording eight parameters *viz.,* seedling length (cm), seed density (g/cc), germination (%), seedling dry weight (mg), vigour index I, vigour index II, electrical conductivity (µS/cm/seed) and accelerated ageing at 48 and 72 hours. All these vigour parameters were measured in each of the three replications.

For calculating standard germination, one hundred seeds of each genotypes per replication were placed in between moistened rolled towel papers and kept at 20ºC in seed germinator. The final count was taken on 7th day and normal seedlings were considered for recording per cent germination [7]. Seedling length (shoot + root) was measured in centimeter by taking average of ten randomly selected normal seedlings among them used for calculation of standard germination per replication. Those seedlings, whose length was measured, were dried in hot air oven for 24 hours at 80 ± 1ºC and then their dry weight was measured. Average dry weight of each genotype was calculated and expressed in milligrams.

Seed density was measured by taking one hundred seeds per replication of each genotype and weighed on electrical balance. These seeds were dipped in water having density of 1.0 at 20°C. The volume of water replaced by the seeds was recorded and seed density was calculated by using the formula:

$$\text{Seed density} = \frac{\text{Weight of 100 seeds (g)}}{\text{Volume of water replaced by seeds (cm}^3\text{)}}$$

The seedling vigour indices were calculated [8] as follows:

Vigour Index I= Standard germination (%) x seedling length (cm)
Vigour Index II = Standard germination (%) x seedling dry weight (mg)

Electrical conductivity of seed leachates was measured to know the status of membrane permeability. For this, 100 healthy seeds per replication were soaked in 50 ml deonized water in 100 ml beakers. Seeds were emerged completely and beakers were covered with silver foil and these samples were kept for 24 hours at 25 °C. The electrical conductivity of the seed leachates was measured by using conductivity meter and computed in µS/cm/seed.

For accelerated ageing test, seeds were placed in a single layer on the wire mess trays fitted in plastic boxes. Each

box contained about 40 ml of distilled water. The boxes were placed in ageing chamber after closing their lids. The seeds were aged at 40±1°C for different time intervals (48 h and 72 h) and tested for standard germination per replication of 100 seeds each. The number of normal seedlings were counted on 7th day according to the rules of International Seed Testing Association and expressed in percentage.

The mean performance of individual genotype was recorded and employed for statistical analysis. Analysis of variance to test the significance for each character was carried out as per methodology advocated by [9] and described by [10]. Phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were calculated by the formula given by [11], heritability in broad sense (h^2) was calculated by using the formula suggested by [12] and genetic advance that is the expected genetic gain was calculated by using the procedure given by [13].

RESULTS AND DISCUSSION

The details of the genotypes used in the study are provided in Table 1 which indicates the appropriate representation of both 2-row (17) and 6-row (33) types. The analysis of variances revealed significant differences among the genotypes for all the characters studied indicating presence of substantial genetic variability among the genotypes under timely (Table 2) as well as under late sown (Table 3) conditions. [14] also evaluated the seeds of barley by different vigour and viability tests at different harvest times.

Mean performance: Promising genotypes are listed in Table 4 for timely sown and in table 5 under late sown which were found significantly superior over the mean. Under timely sown, three genotypes were found promising for seedling length and was recorded highest in 2nd GSBSN (42.33cm). However, for this trait under late sown, 12 genotypes showed superiority among which BH 14-42 exhibited maximum seedling length (38.30 cm).Seed density was highest in IBYT-HI-17*i.e.* 2.10 g/cc among eight promising genotypes under timely and 1.75g/cc in RD 2909 under late sown among six superior genotypes. One genotype each depicted significant superiority for germination (%) under both the environments namely UPB 1059 (100 %) for timely and AZAD (99.67 %) under late sown. [15] also studied germination (%), root length, shoot length, seedling length and seed index vigour in barley breeding lines. Among six promising genotypes under timely and eight for late sown, highest seedling dry weight was recorded in BH 15-17 (230.3 mg) and 2ndGSBSN-28 (2015) (195.1 mg) for timely and late sown, respectively. Vigour index-I was maximum in 2nd GSBSN-28 (2015) (3996.4) among three and in BH 14-42 (3763.5) among ten superior genotypes likewise, vigour index-II was highest in BH 15-17 (22642.7) among six and 2nd GSBSN-28 (2015) (18597.4) out of seven significant superior genotypes under timely and late environments, respectively. [16] reported performance of established genotypes that showed variations associated with differences in seed vigour that may be physical, physiological or genetic in nature and also recognized seed vigour as a component

Table 2. Analysis of variance of different seed quality traits in barley under timely sown condition

Source of variation	DF	SL	SD	GP	SDW	VI	VII	EC	AA48	AA72
Replications	2	1.48	0.05	1.22	47.15	31441.50	158878.25	0.002	47.76	140.48
Genotypes	49	13.04**	0.31**	1.18*	1197.04**	112277.80**	11580216.51**	0.007**	393.92**	434.30**
Error	98	3.55	0.03	0.99	115.68	32655.01	1104714.05	0.0003	20.85	26.08

SL: Seedling length, SD: Seed density, GP: Germination (%), SDW: Seedling dry weight, VI: Vigour index I, VII: Vigour index II, EC: Electrical conductivity, AA48: Accelerated ageing at 48hours, AA72: Accelerated ageing at 72 hours; *, **Significant at 0.05 and 0.01 level, respectively

Table 3. Analysis of variance of different seed quality traits in barley genotypes under late sown condition

Source of variation	DF	SL	SD	GP	SDW	VI	VII	EC	AA48	AA72
Replications	2	8.76	0.004	4.35	219.98	122148.31	2366007.25	0.004	30.48	70.65
Genotypes	49	37.09**	0.11**	15.98**	1389.57**	423327.76**	13720853.07**	0.007**	263.95**	809.30**
Error	98	3.14	0.03	3.39	152.83	43481.20	2101734.35	0.0006	28.85	28.58

SL: Seedling length, SD: Seed density, GP: Germination (%), SDW: Seedling dry weight, VI: Vigour index I, VII: Vigour index II, EC: Electrical conductivity, AA48: Accelerated ageing at 48hours, AA72: Accelerated ageing at 72 hours; **Significant at 0.01 level

Table 4. Promising barley genotypes for various seed quality traits under timely sown condition

Sr. No.	Seed quality traits	Promising Genotypes*
1.	Seedling length (cm)	IBYT-HI-17 [40.0], 2nd GSBSN-28 (2015) [42.33] and MGL-117 [40.0]
2.	Seed density (g/cc)	IBYT-HI-17 [2.13], MBGSN 145 [1.54], 2nd GSBYT-02 (2015) [1.60], MGL-117 [1.61], IBON-HI-1 (2015-16) [1.91], IBON-HI-3 (2015-16) [2.10], IBON-HI-37 (2015-16) [1.77], INBON-15-16 [1.71]
3.	Germination (%)	UPB 1059 [100.0]
4.	Seedling dry weight (mg)	IBYT-HI-17 [204.30], 2nd GSBYT-02 (2015) [209.90], DWRB 101 [192.63], 2nd GSBSN-15-35 [214.10], BH 13-26 [197.83], BH 15-17 [230.30]
5.	Vigour index I	2nd GSBSN-28 (2015) [3996.40], MGL-58 [3913.83], MGL-117 [3906.60]
6.	Vigour index II	IBYT-HI-17 [20304.47], 2nd GSBYT-02 (2015) [20500.23], DWRB 101 [18940.83], 2nd GSBSN-15-35 [20767.70], BH 13-26 [19721.37], BH 15-17 [22642.73]
7.	Electrical conductivity (µS/cm/seed)	IBYT-HI-13 [0.27], IBYT-HI-16 [0.23], IBYT-HI-18 [0.22], IBYT-HI-15 [0.28], HUB 242 [0.29], 2nd GSBYT-02 (2015) [0.27], DWRB 101 [0.29], MGL 105 [0.27], IBON-HI-3 (2015-16) [0.28], 2nd GSBSN-15-8 [0.21], 2nd GSBSN-15-35 [0.23], BH 13-20 [0.29], BH 14-25 [0.21], BH 946 [0.24]
8.	Accelerated ageing (48 h)	IBYT-HI-19 [90.67], IBYT-HI-15 [90.67], IBYT-HI-20 [94.00], UPB 1059 [88.00], 2nd GSBSN-28 (2015) [90.00], 2nd GSBSN-60 (2015) [96.00], MGL-64 [91.33], MGL-117 [89.33], DWRB 143 [94.67], BH 13-26 [92.00], BH 15-17 [90.67]
	Accelerated ageing (72 h)	IBYT-HI-19 [85.33], IBYT-HI-15 [84.00], IBYT-HI-20 [88.67], 2nd GSBYT-23 (2015) [82.67], 2nd GSBSN-60 (2015) [80.67], MGL-64 [84.00], IBON-HI-3 (2015-16) [78.67], BH 902 [80.67], AZAD [80.00], DWRB 143 [88.67], BH 13-26 [80.00], BH 15-30 [80.00], DWRUB 52 [80.67]

*Significantly diverse genotypes with respect of C.D. in view of mean, Values in parenthesis indicates mean value of genotype for concerned trait

Table 5. Promising barley genotypes for various seed quality traits under late sown condition

Sr. No.	Seed quality traits	Promising Genotypes*
1.	Seedling length (cm)	MBGSN 145 [37.10], RD 2909 [35.47], K 560 [36.10], 2nd GSBYT-02 (2015) [36.73], IBON-HI-13 (2015-16) [35.37], IBON-HI-37 (2015-16) [35.70], IBON-HI-67 (2015-16) [36.23], AZAD [36.37], DWRB 143 [38.13], BH 13-26 [36.50], BH 14-25 [35.27], BH 14-42 [38.30]
2.	Seed density (g/cc)	BH 959 [1.60], RD 2909 [1.75], IBON-HI-1 (2015-16) [1.51], BH 13-20 [1.52], BH 14-25 [1.50], BH 946 [1.51]
3.	Germination (%)	AZAD [99.67]
4.	Seedling dry weight (mg)	IBYT-HI-17 [168.37], BH 959 [161.23], DWR 123 [167.07], DWR 137 [180.00], MBGSN 145 [182.30], 2nd GSBSN-28 (2015) [195.07], K 560 [163.57], BH 15-17 [188.37]
5.	Vigour index I	MBGSN 145 [3586.23], K 560 [3583.53], 2nd GSBYT-02 (2015) [3623.30], MGL-117 [3433.33], IBON-HI-37 (2015-16) [3497.47], IBON-HI-67 (2015-16) [3549.60], AZAD [3621.23], DWRB 143 [3721.73], BH 13-26 [3585.93], BH 14-42 [3763.53]
6.	Vigour index II	IBYT-HI-17 [16978.23], DWR 137 [17262.63], MBGSN 145 [17621.57], RD 2904 [16541.23], 2nd GSBSN-28 (2015) [18597.37], K 560 [16251.73], BH 15-17 [17607.43]
7.	Electrical conductivity (µS/cm/seed)	IBYT-HI-13 [0.39], IBYT-HI-17 [0.40], IBYT-HI-16 [0.40], IBYT-HI-18 [0.35], IBYT-HI-15 [0.38], DWR 123 [0.39], 2nd GSBSN-60 (2015) [0.40], MGL-117 [0.39], IBON-HI-3 (2015-16) [0.40], 2nd GSBSN-15-8 [0.37], INBON-15-22 [0.38], DWRB 143 [0.40], BH 946 [0.39]
8.	Accelerated ageing (48 h)	IBYT-HI-16 [93.33], IBYT-HI-18 [96.00], IBYT-HI-20 [94.67], 2nd GSBSN-60 (2015) [96.67], INBON-15-16 [94.67], AZAD [94.67], BH 15-17 [96.00]
	Accelerated ageing (72 h)	IBYT-HI-16 [90.00], IBYT-HI-18 [83.33], IBYT-HI-15 [75.33], IBYT-HI-20 [74.67], BH 959 [77.33], DWR 123 [73.33], MBGSN 145 [80.67], RD 2909 [79.33], HUB 242 [79.33], 2nd GSBSN-28 (2015) [75.33], 2nd GSBSN-60 (2015) [80.00], IBON-HI-13 (2015-16) [74.67], IBON-HI-67 (2015-16) [82.67], BH 902 [82.67], INBON-15-16 [80.67], AZAD [89.33], BH 13-20 [77.33], BH 15-17 [73.33], BH 946 [82.00]

*Significantly diverse genotypes with respect of C.D. in view of mean, Values in parenthesis indicates mean value of genotype for concerned trait

of seed quality distinct from germinability. They also report wide range and high degree of variability for all characters studied. Out of fourteen and thirteen better genotypes observed for electrical conductivity, 2ndGSBSN-15-8 and BH 14-25 (0.21µS/cm/seed) under timely and IBYT-HI-18 (0.35 µS/cm/seed) under late sown condition, respectively performed best. [17] mentioned the measurement of electrical conductivity as an assessment of seed vigour. [6] also report significant difference among different barley varieties for electrical conductivity. Accelerated ageing (48 h) was found maximum in genotype *viz*., 2nd GSBSN-60 (2015) *i.e.* 96.0 & 96.7 % germination under timely and late sown environment, respectively. Two genotypes namely DWRB 143 and IBYT-HI-20 (88.67) had maximum accelerated ageing (72 h) under timely sown while in case of late sown it was highest for IBYT-HI-16 (90.0). [18] also studied various traits *viz*., percentages of viable seeds and germination, electrical conductivity of seed leachates, germination rate, seedling dry weight and root and shoot dry weight in barley.

Genetic variability

The estimates of genetic variability for all the characters are presented in Table 6&7. In general, the results under investigation revealed wide range for all the traits under both the environments.

[19] also studied the seed vigour of barley varieties under different locations. The estimates of phenotypic coefficients of variation (PCV) were greater than genotypic coefficients of variation (GCV) for all the characters under study in both timely as well as under late sown conditions. Among all the traits, seed density had highest phenotypic and genotypic coefficient of variation followed by accelerated ageing (72 h) under timely sown, however, under late sown accelerated ageing (72 h) exhibited highest PCA and GCV. Moderate phenotypic and genotypic coefficients of variation were recorded for rest of the traits under both environments indicating availability of sufficient genetic variability and thus exhibited scope for genetic improvement. However, germination (%), vigour index-I and seedling length under timely sown and germination (%) under late sown revealed least phenotypic and genotypic coefficients of variation. [20] concluded electrical conductivity (EC) as a possible method for measuring viability and seedling vigour in wheat and other crops and also reported significant differences among selected seed lots in most of the parameters of seed quality.

The estimates of heritability as depicted in Table 6 ranged from 5.78 per cent for germination (%) to 88.84 per cent for electrical conductivity under timely sown while under late sown (Table 7), from 45.21 per cent for seed density to 90.11 per cent for accelerated ageing (72 h). For timely sown, moderate to high heritability in broad sense estimated for all the traits except germination (%), vigour index-I and seedling length which exhibited low heritability. All the traits under late sown except of seed density and germination (%) showed moderate to high heritability.

It is evident from results that highest genetic advance as per cent of mean was observed for seedling density followed by accelerated ageing (72 h) and electrical conductivity under timely sown environment. Similarly under late sown, three traits *i.e.* accelerated ageing (72 h), seedling dry weight and vigour index-I showed high genetic advance. However, germination (%) exhibited lowest genetic advance under both growing conditions.

Table 6. Estimates of genetic variability for different seed quality traits in barley under timely sown condition

Sr. No.	Seed quality traits	Mean ± S.E. (d)	Range	Coefficient of variation (%)		Heritability (bs) (%)	Genetic advance (% mean)
				PCV	GCV		
1	Seedling length (cm)	39.59±1.54	30.50-40.00	7.08	4.86	47.16	6.87
2	Seed density (g/cc)	1.24±1.54	0.60-2.37	28.57	24.47	73.37	43.19
3	Germination (%)	98.96±0.81	95.0-100.0	1.03	0.25	5.78	0.12
4	Seedling dry weight (mg)	170.46±8.78	121.40-251.70	12.80	11.13	75.70	19.96
5	Vigour index I	3605.73±47.55	3029.4-4106.2	6.74	4.51	44.83	6.23
6	Vigour index II	16820.34±858.18	12018.6-24666.6	12.74	11.11	75.96	19.94
7	Electrical conductivity (µS/cm/seed)	0.318±0.01	0.20-0.44	16.78	15.82	88.84	30.72
8	Accelerated ageing (48 h)	80.36±3.73	38.0-98.0	14.99	13.88	85.64	26.45
	Accelerated ageing (72 h)	70.20±4.17	34.0-92.0	18.14	16.62	83.91	31.35

Table 7. Estimates of genetic variability for different seed quality traits in barley under late sown condition

Sr. No.	Seed quality traits	Mean ± S.E. (d)	Range	Coefficient of variation (%)		Heritability (bs) (%)	Genetic advance (% mean)
				PCV	GCV		
1	Seedling length (cm)	32.15±1.45	21.00-39.20	11.82	10.46	78.25	19.06
2	Seed density (g/cc)	1.21±0.14	0.72-1.91	19.52	13.12	45.21	18.18
3	Germination (%)	96.27±1.50	89.0-100.0	2.86	2.12	55.34	3.26
4	Seedling dry weight (mg)	139.94±10.09	92.30-198.10	16.98	14.50	72.95	25.52
5	Vigour index I	3093.63±170.26	1869.0-3880.8	13.33	11.50	74.43	20.44
6	Vigour index II	13466.31±1183.70	7801.6-20384.0	18.15	14.61	64.82	24.23
7	Electrical conductivity (µS/cm/seed)	0.44±0.02	0.33-0.66	11.99	10.62	78.33	19.36
8	Accelerated ageing (48 h)	83.52±4.39	44.0-98.0	12.39	10.59	73.09	18.66
	Accelerated ageing (72 h)	63.39±4.36	16.0-96.0	26.81	25.44	90.11	49.76

The estimates of heritability are more advantageous when expressed in terms of genetic advance. Moderate to high heritability coupled with high genetic advance under timely sown was observed for seedling density, accelerated ageing (72, 48 h) and electrical conductivity likewise, for accelerated ageing (72 h), seedling dry weight and vigour index-I under late sown indicating the importance of these seed vigour traits in crop improvement. [21] elucidated significant variations between treatments for the traits *viz*., germination percentage, germination index, energy of germination, mean germination time, seedling vigour, seedling length, seedling fresh and dry weight in barley.

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