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ASSESSMENT OF GENETIC VARIABILITY AND INTERRELATIONSHIP BETWEEN MALT YIELD AND SEED TRAITS IN TWO-ROWED AND SIX-ROWED BARLEY (*HORDEUM VULGARE* L.)

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SUMMARY

A total of 20 genotypes of two-rowed and six-rowed barley were used to study the genetic variability for different seed traits as well as their interrelationship with malt yield. Significant differences were observed among the genotypes regarding all the characters studied. Estimates of heritability, genotypic and phenotypic coefficients of variability were found higher in electrical conductivity followed by accelerated ageing and standard germination. High genetic advance coupled with high heritability was also found for electrical conductivity, accelerated ageing and standard germination. In pooled association analysis, malt yield had positive and significant correlation with accelerated ageing and standard germination. However, in independent analysis of two-rowed barley, malt yield was found negatively and significantly correlated with seedling vigour and seedling length. Path analysis showed that accelerated ageing and standard germination had the highest direct effect on malt yield indicating the importance of these traits in selection and crop improvement for malt yield.

Key words : Variability, association, path analysis, seed traits, malt yield, *Hordeum vulgare*

Barley is an important feed and industrial crop in India. It is considered as poor man's crop because of its low inputs requirement and better adaptability to harsh environments like drought, salinity/alkalinity and marginal land. In the modern time, it is popularly being preferred as medicinal food in urinary as well as diabetes problems. It may be utilized as source of green fodder under water scarcity conditions. In addition to direct human consumption, barley is utilized by the beer industries, food processing industries and feed manufacturing industries in India. So, increase in barley grain production and improving malt quality is a need of growing beverage industry as well as food consumption in the world. Malt is germinated cereal grains that have been dried in a process known as "malting". The quality and quantity of malt extract depends on many seed and malt factors. Assessment of the genetic diversity in a crop species is fundamental to its improvement. Genetic diversity among and within plant species is in danger of being reduced. In wild species, genetic diversity may be lost because of severe reduction in population size, whereas in domesticated crops genetic diversity may be lost because of the narrow genetic base in many breeding programmes. To measure the germination ability of the seed lot, ISTA has proposed an excellent called as standard germination test (Verma *et al*., 1998). It showed that increase in conductivity value of the seed leachates at different soaking periods was related to the degree of deterioration of seed lots of *Brassica* species. Also, vigour of seed lot was estimated by various workers using electrical conductivity test i. e. Vanzolini and Nakagawa (2005) in peanut and Kharb (1992) in pigeonpea. Raikwar and Vishwakarma (2003) conducted an experiment on 88 diverse barley accessions and reported that a wide range of variation existed for the characters tillers/plant, spike length, grain weight, grains/spike, harvest index and seed shape. In addition to contributing to malt yield, seed traits can also be utilized to identify the desirable genotypes at early stages if they show positive association with yield (López-Castañeda *et al.*, 1996) and malting traits. It can greatly facilitate the breeders in screening larger populations and accelerating their selection programmes. Therefore, the present investigation was undertaken to study the genetic variability for different seed traits as well as their interrelationship with malt yield to facilitate the malt barley breeding in the country.

The prescribed experiment was conducted at CCS Haryana Agricultural University, Hisar during **rabi** 2010-11. A set of these 20 genotypes (10 two-rowed and 10 six-rowed) of barley given in Table 1, was grown in the Department of Genetics & Plant Breeding and harvested material was used for analyzing malt yield and seed traits.

TABLE 1
List of barley genotypes

S. No.	Six-rowed barley	S. No.	Tow-rowed barley
1.	BH 393	11.	DWRUB 52
2.	BH 902	12.	RD 2668
3.	BH 932	13.	BH 885
4.	BH 933	14.	BH 935
5.	BH 946	15.	BH 927
6.	BH 947	16.	BH 942
7.	BH 948	17.	BH 952
8.	RD 2552	18.	BH 953
9.	K 551	19.	BH 954
10.	DWRUB 64	20.	DWR 91

The seed traits were tested in Seed Science and Technology Laboratory at CCSHAU, Hisar. Standard germination (%) was tested by using one hundred seeds of each genotype in three replicates placed in between sufficient moistened rolled towel papers (BP) and kept at 20^{o}C in seed germinator. The final count was taken on 7th day and only normal seedlings were considered for per cent germination according to the rules of International Seed Testing Association (ISTA, 2004). Seedling vigour indices were calculated by the formula of Seedling vigour index : Standard germination (%) × Seedling length (cm). To measure the electrical conductivity, 50 normal and uninjured seeds in three replications were soaked in 75 ml deionized water in 100 ml beakers. Seeds were immersed completely in water and beakers were covered with foil. Thereafter, these samples were kept at 25^{o}C for 24 h. The electrical conductivity of the seed leachates was measured using a direct reading conductivity meter. The conductivity was expressed in µS/cm/seed. For accelerated ageing 100 seeds were put in between paper (BP) for germination after ageing of 96 h at 40±1^{0}C temperature, kept in the germinator at 200 for seven days.

The malt yield was tested in DWR, Karnal malt testing laboratory as described by Yadav and Jagshoran (1999). The experimental data were subjected to the analysis of variance as suggested by Panse and Sukhatme (1967). Heritability, genetic advance, coefficient of variance and correlation coefficient were worked out as per the method given by Al-Jibouri *et al.* (1958). Path coefficient analysis was done by using correlation coefficients as suggested by Dewey and Lu (1959) by taking malt yield as dependent variable and seed traits as independent variables in each two-rowed barley and six-rowed barley and also for the pooled data.

Analysis of variance revealed significant differences for all the seven characters studied. Variance due to genotype was highly significant for all the seven characters indicating the presence of sufficient variability in the genotypes selected for this study (Verma and Verma, 2011; Singh, 2011). High phenotypic coefficient of variation (PCV) along with genotypic coefficient of variation (GCV) was also noted for electrical conductivity and accelerated ageing. High values of heritability (h^2) were recorded for electrical conductivity, accelerated ageing, standard germination and malt yield. Whereas very low heritability was also found for seedling length and field establishment indicating high environmental influences. High values of genetic advance were also recorded for grain electrical conductivity, accelerated ageing and standard germination. Whereas malt yield had moderate values for genetic advance. Therefore, wide range, high coefficients of variation, high heritability coupled with high genetic advance as per cent of mean were recorded for electrical conductivity, accelerated ageing, standard germination and malt yield in pooled as well as independent analysis of two-rowed and six-rowed barley revealed the possibility of their further improvement (Table 2).

Phenotypic correlation coefficients were computed for malt yield, standard germination, seedling length, accelerated ageing, electrical conductivity, field establishment, seedling vigour index of pooled as well as separate for six-rowed and two-rowed type barley and results are presented in Table 3 (Arun *et al.*, 2013). In pooled analysis of six-rowed and two-rowed type, malt yield had positive and significant correlation with accelerated ageing and standard germination (%). But malt yield was found negatively and non-significantly associated with seedling length and seedling vigour. Seedling vigour index was found positively and

TABLE 2
Mean, range, PCV, GCV, heritability (h^2) and GA of barley genotypes for malt yield and seed traits

Character	Mean	Range	PCV	GCV	h^2 (bs)	GA (% of mean)
Pooled analysis						
Standard germination (%)	93.3	86.00-96.67	5.41	5.27	0.95	10.57
Seedling length (cm)	35.0	32.40-39.60	4.42	2.31	0.27	2.48
Seedling vigour index	3265.7	2902.6-3801.6	3.73	3.48	0.87	6.69
Accelerated ageing (%)	82.1	73.67-87.00	6.84	6.67	0.95	13.39
Electrical conductivity	0.18	0.101-0.229	18.62	18.41	0.98	27.50
Field establishment (%)	88.0	81.67-92.00	3.95	2.35	0.35	2.87
Malt yield (%)	86.6	79.07-90.67	3.97	3.79	0.91	7.44
Six-rowed						
Standard germination (%)	92.2	86.00-96.67	5.14	4.52	0.92	8.95
Seedling length (cm)	34.68	32.40-37.00	4.70	2.53	0.24	2.57
Seedling vigour index	3197.6	2902.6-3453.3	4.58	4.33	0.89	8.42
Accelerated ageing (%)	81.26	73.67-87.00	5.72	5.48	0.94	10.81
Electrical conductivity	0.164	0.101-0.228	13.27	13.09	0.98	17.21
Field establishment (%)	86.96	81.67-92.00	4.89	2.79	0.32	3.29
Malt yield (%)	85.95	79.07-90.67	4.67	4.51	0.93	8.97
Two-rowed						
Standard germination (%)	94.5	92.00-96.67	6.11	6.00	0.96	12.15
Seedling length (cm)	35.32	32.60-39.60	3.4	1.28	0.14	1.003
Seedling vigour index	3333.7	2998.0-3801.6	2.53	2.27	0.80	4.18
Accelerated ageing (%)	82.83	80.00-86.67	7.42	7.30	0.97	14.82
Electrical conductivity	0.198	0.174-0.229	8.71	8.28	0.90	16.21
Field establishment (%)	88.96	87.00-92.00	2.52	1.06	0.18	0.93
Malt yield (%)	87.21	81.00-90.33	3.22	2.98	0.85	5.68

significantly correlated with seedling length, standard germination, accelerated ageing and field establishment. Similar correlations were found in case of separate analysis of six-rowed type.

Whereas, in two-rowed type malt yield had positive and significant correlation with accelerated ageing but negatively and significantly correlated with seedling length and seedling vigour index. This negative correlation may be due to utilization of starch by seedling in growth which to be converted in malt sugar. Field establishment had positive and significant correlation with seedling length, standard germination (%) and seedling vigour. Field establishment was not associated significantly with malt yield but due to its positive and significant correlation with standard germination (%) can be used in indirect selection.

The results of path analysis i. e. direct and indirect effects are given in Table 4. Path analysis with pooled data showed that accelerated ageing had the highest direct effect on malt yield, followed by standard germination (Budakli and Celik, 2012). Also in independent analysis among six-rowed type barley, accelerated ageing had the highest direct effect on malt yield, followed by standard germination. Whereas among two-rowed types, standard germination had highest direct effect on malt yield.

It was concluded that accelerated ageing and standard germination appeared to be the prominent characters when selecting for malt yield in barley, because of their highly significant phenotypic correlations with malt yield. These characters also had the highest direct effects on malt yield and high indirect effects through most of the other characters. This investigation, therefore, suggests that accelerated ageing and standard germination should be given maximum consideration as selection indices for malt yield improvement in barley.

TABLE 3
Phenotypic correlation coefficients among malt yield and seed traits in barley

Characters	SL	AA	EC	SG	SV	MY
Pooled analysis						
FE	0.201	0.516**	0.176	0.854**	0.626**	0.139
SL		0.067	0.099	0.170	0.890**	-0.235
AA			0.001	0.799**	0.286*	0.434**
EC				0.105	0.169	0.041
SG					0.528**	0.322*
SV						-0.134
Six-rowed						
FE	-0.089	0.580**	-0.020	0.863**	0.573**	0.213
SL		0.112	-0.026	0.042	0.765**	0.080
AA			-0.231	0.859**	0.450*	0.397*
EC				-0.138	-0.020	-0.160
SG					0.582**	0.349*
SV						0.183
Two-rowed						
FE	0.464**	0.184	-0.021	0.732**	0.678**	0.246
SL		-0.080	0.0770	0.248	0.966**	-0.698**
AA			0.110	0.589**	-0.008	0.445*
EC				-0.012	0.054	0.210
SG					0.423*	0.085
SV						-0.649**

FE–Field establishment, SL–Seedling length, AA–Accelerated ageing, EC–Electrical conductivity, SG–Standard germination, SV–Seedling vigour and MY–Malt yield. *,**Significant at P=0.05 and P=0.01 levels, respectively.

TABLE 4
Phenotypic direct (main diagonals) and indirect path coefficients

Characters	SG	SL	AA	EC	FE	SV	MY
Pooled analysis							
FE	**0.125**	0.294	0.049	0.037	0.064	-0.430	0.139
SL	0.097	**0.069**	0.020	0.021	0.013	-0.454	-0.235
AA	0.090	0.202	**0.290**	0.002	0.060	-0.209	0.434
EC	0.193	0.126	0.101	**0.108**	0.008	-0.496	0.041
SG	0.266	0.177	0.131	0.022	**0.275**	-0.549	0.322
SV	0.160	0.195	0.083	0.035	0.040	**-0.646**	-0.134
Six-rowed							
FE	**0.226**	0.250	0.217	-0.103	-0.333	-0.244	0.213
SL	-0.015	**0.233**	0.103	-0.004	-0.016	-0.221	0.080
AA	0.154	0.114	**0.329**	-0.033	-0.131	-0.036	0.397
EC	-0.325	-0.506	-0.007	**0.145**	0.053	0.481	-0.160
SG	0.270	-0.185	0.025	-0.020	**0.335**	-0.077	0.349
SV	0.145	0.386	0.013	-0.003	-0.224	**-0.134**	0.183
Two-rowed							
FE	**-0.156**	-0.714	0.332	-0.006	0.203	0.486	0.246
SL	-0.527	**-0.206**	-0.138	0.022	0.035	0.116	-0.698
AA	-0.765	0.992	**0.220**	0.032	0.083	-0.115	0.445
EC	0.085	-0.945	0.124	**0.187**	-0.002	0.760	0.210
SG	-0.142	-0.159	0.029	-0.004	**0.240**	0.120	0.085
SV	-0.416	-0.402	-0.202	0.016	0.159	**0.197**	-0.649

Abbreviation details are given in Table 3.

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