Indian Journal of Agricultural Sciences **78** (10): 853–7, October 2008

Association of important malting traits in barley (*Hordeum vulgare*)

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Received: 5 January 2008

ABSTRACT

An experiment was conducted during 2003–05 to study genetic variability, genotypic and phenotypic correlation co-efficients for 13 malting quality traits in a set of 131 barley (*Hordeum vulgare* L) genotypes grown at 2 locations. Significant genetic variability was observed for all the 13 characters studied. Significant location effects for most of the quality traits were observed. There were significant genotypic and phenotypic correlation co-efficients between 60 pairs of characters, 35 with positive and 25 with negative associations. Hot water extract, the most important malt quality trait showed significant correlation data with grain (hectolitre weight, 1 000 g weight, bold grain) and malt (friability and homogeneity) quality traits.

Key words: Barley, Crop improvement, Genetic variability, Genotypic, Malting quality, Phenotypic correlation

Barley (*Hordeum vulgare* L.) is cultivated since ancient times and mostly being used as cattle feed and small fraction also utilized for human consumption. However in recent times the demand of barley for malting purposes has been enhanced with the increasing number of breweries and preferences of malted food and energy drinks in the modern society, especially for kids as baby foods products. The barley produce from irrigated fertile areas is mainly used for industrial purposes, which amounts to nearly 20–25% of the total production and the remaining quantity from rainfed and less fertile areas are utilized for cattle feed purposes. The barley varieties that are being cultivated was not meeting the minimum standard for various grain and malt traits for classification as malting grade barley (Verma *et al*. 2000). Therefore, the development of high-yielding spring malt barley cultivars has become a necessity to meet the industrial demand of malt in the country. There are number of grain and malt traits that are being considered important by malting and brewing industries as the requirement of industry varies for different end products.

High protein barley is desirable for energy drinks and baby food products, where as low protein is desirable for brewing industry. To evaluate and classify the new barley variety as malt or non-malt type, the minimum acceptable standards for various grain and malt traits have been identified (Verma *et al*. 2005). However amongst them hot water extract, diastatic power, friability, homogeneity and hectolitre weight, Kolbach index etc are considered to be the more important from brewing point of view (Wright 2000). Majority of these traits are interrelated and also influenced by the environment/ climatic conditions (Sewa Ram and Verma 2002). Therefore, it is desirable to understand the genetic relationship among various quality traits and their genetic diversity available in parental lines before making a comprehensive breeding strategy for improvement of malting quality in Indian barley cultivars. The present investigation was undertaken to study the genetic variability for different grain and malt quality traits as well as their interrelationship to facilitate the malt barley breeding in the country.

MATERIALS AND METHODS

A set of 131 barley genotypes, including 2-row (98) and 6-row (33) types were used in a field experiment carried out at Karnal and Patiala during 2003–04 and 2004–05. The materials consisted of released varieties, elite germplasm accessions and advanced breeding lines of indigenous and exotic origin. The sowings were done in second week of November at both places during each year. Exotic accessions (89) used include released varieties and germplasm accessions from different countries (Canada, Australia, Denmark, USA and Argentina) as well as selections from international observation nurseries from CIMMYT (Mexico) and ICARDA (Syria).

The material was grown in a compact block with 2 rows of 2 m length for each genotype, with 30 cm row-to-row spacing with 2 replications. Recommended agronomic

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Table 1 Mean sum of square for grain and malt quality traits

Source	df	Trait*											
		HWE	BD	Bold	Thin	GP	TGW	Husk	MF	MH	DP	Vis	FR	KI
Replication	1	3.63*	0.32	11.31	0.5	0.48	0.38	0.11	0.001	0.030	0.61	0.0001	10.45	0.00002
Environment	1	0.33	15.80*	1349.77*	201.69*	317.21***	87.48***	97.81***	9.08*	7.81	0.27**	0.17***	1532.09***	0.03***
Interaction	1	0.26	3.2	291.75**	41.4**	14.21***	2.48	6.15*	1.60	5.98	0.03	0.01***	0.27	0.001***
Treatments	130	32.68***	47.5***	565.25**	52.04***	3.97***	93.22***	7.20***	769.15***	360.60***	1153.49***	0.05***	4553.51***	0.04***
Error	390	0.89	2.15	28.86	3.86	0.80	4.68	1.27	7.37	2.97	52.89	0.0007	369.01	0.00004

*HWE, Hot water extract; BD, bulk density (hectolitre weight)
Bold, proportion of bold grains; Thin, proportion of thin grains
GP, grain protein; TGW, 1 000 grain weight; Husk, husk content; MF, malt friability; MH, malt homogeneity
DP, diastatic power; Vis, wort viscosity; FR, wort filtration rate; KI, Kolbach index

package of practices were followed to raise a good crop. The genotypes were harvested during second week of April in each year at both the locations and the grain samples from each location were evaluated for number of grain and malt quality traits.

In case of grain traits observations were recorded on grain uniformity, ie proportion of plump (bold%) and thin grains (thin %), husk content, 1 000 grain weight, hectolitre weight (bulk density) in kg/hectolitre and grain protein (%) content. Barley grain samples (100 g each) of each genotype from both locations were micro-malted through automatic micro-malting system, following a 14 hr steeping, 96 hr germination and 30–32 hr kilning cycle.

The malt, thus obtained from each genotype was analyzed for important malt quality traits like, malt friability (%), malt homogeneity (%), hot water extract (%), wort filtration rate (ml/hr), Kolbach index, wort viscosity and malt diastatic power. All these parameters were analyzed as per EBC-Analytica IV 2003, while the diastatic power was analyzed as the total enzymatic activity of the amylases in malt samples as per Institute of Brewing (I0B) method (IOB 1997).

The data for analysis of variance (ANOVA) were analyzed as suggested by Panse and Sukhatme (1961). The genotypic and phenotypic correlation co-efficients were estimated for each location as well as on pooled basis across 2 locations over 2 years as per the method given by Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) revealed non-

Table 2 Mean, range, genotypic and phenotypic co-efficients of variation grain and malt traits in barley

Trait	Mean + SE	Range		GCV	PCV
		Minimum	Maximum	(%)	(%)
HWE (%)	77.93±0.47	69.3	85.7	3.61	3.66
Bulk density (kg/hl)	61.80±0.73	50.5	71.0	5.44	5.57
Bold (%)	83.24±2.67	41.0	99.0	13.92	14.29
Thin (%)	3.57±0.98	0.10	24.4	97.26	101.04
GP (%)	12.96±0.45	9.5	16.2	6.86	7.69
TGW (g)	45.79±1.08	30.0	59.0	10.27	10.54
Husk (%)	11.84±0.57	7.9	15.8	10.28	11.33
MF (%)	56.07±1.36	30.0	86.0	24.61	24.73
MH (%)	87.01±0.86	36.0	99.0	10.87	10.91
DP (°L)	105.93±3.64	29.0	149.0	15.66	16.03
Vis (mpas)	1.48±0.01	1.280	2.228	7.79	7.85
FR (ml/hr)	267.27±9.60	112.1	332.0	12.10	12.62
KI	0.47±0.003	0.28	0.89	22.76	22.77

*HWE, Hot water extract; BD, bulk density (hectolitre weight); Bold, proportion of bold grains; Thin, proportion of thin grains; GP, grain protein; TGW, 1 000 grain weight; Husk, husk content; MF, malt friability; MH, malt homogeneity; DP, diastatic power; Vis, wort viscosity; FR, wort filtration rate; KI, Kolbach index

Table 3 Genotypic and phenotypic correlation co-efficient among grain and malt quality traits in barley

Traits		BD (kg/hl)	Bold (%)	Thin (%)	GP (%)	TGW (g)	Husk (%)	MF (%)	MH (%)	DP (oL)	Vis (mpas)	FR (ml/hr)	KI
HWE (%)	GP	0.78***	0.56***	–0.57***	–0.22***	0.53***	–0.39***	0.67***	0.52***	–0.06	–0.09	0.13	0.59***
		0.78***	0.55***	–0.55***	–0.20***	0.53***	–0.36***	0.67***	0.51***	–0.05	–0.09	0.12	0.59***
BD (kg/hl)	GP		0.64***	–0.61***	–0.04	0.51***	–0.44***	0.46***	0.30***	–0.08	–0.13	0.17	0.39***
			0.62***	–0.58***	–0.05	0.50***	–0.42***	0.45***	0.30***	–0.08	–0.13	*0.16	0.38***
Bold (%)	GP			–0.88***	–0.05	0.51***	–0.36***	0.33***	0.18***	–0.13	0.11*	–0.02	0.31***
				–0.88***	–0.08	0.49***	–0.32***	0.33***	0.18***	–0.13	0.10*	–0.02	0.30***
Thin (%)	GP				0.06	–0.49***	0.39***	–0.31***	–0.24***	0.08	–0.11	0.03	–0.32***
					0.10	–0.48***	0.35***	–0.30***	–0.24***	0.08	–0.10	0.02	–0.31***
GP (%)	GP					0.13	–0.07	–0.23***	0.01	0.24***	–0.01	0.03	–0.28***
						0.09	–0.01	–0.20***	0.02	0.22***	0.008	0.03	–0.24***
TGW (g)	GP						–0.38***	0.35***	0.40***	–0.08	0.04	0.14	0.20***
							–0.33***	0.35***	0.39***	–0.08	0.03	0.15	0.19***
Husk (%)	GP							–0.41***	–0.28***	0.23***	0.07	–0.23***	–0.37***
								–0.38***	–0.25***	0.19***	0.07	–0.16***	–0.33***
MF (%)	GP								0.70***	–0.08	–0.21***	0.24***	0.57***
									0.68***	–0.08	–0.21***	0.23***	0.57***
MH (%)	GP									0.14	–0.04	0.21***	0.45***
										0.14	–0.05	0.19***	0.46***
DP (°L)	GP										–0.003	0.14	0.10
											–0.004	0.14	0.10
Vis (mpas)	GP											–0.69***	–0.20***
												–0.68***	–0.20***
FR (ml/hr)	GP												0.18***
													0.18***

*HWE, Hot water extract; BD, bulk density (hectolitre weight); Bold, proportion of bold grains; Thin, proportion of thin grains; GP, grain protein; TGW, 1 000 grain weight; Husk, husk content; MF, malt friability; MH, malt homogeneity; DP, diastatic power; Vis, wort viscosity; FR, wort filtration rate; KI, Kolbach index

significant differences due to replication (Table 1) for all the traits except hot water extract. This indicated that replications had minimum heterogeneity in the experimental plots. Location had highly significant ($P<0.001$) differences for quality characters except for hot water extract and malt homogeneity. This indicated that almost all quality traits were influenced by locations. The influence of environmental/ climatic conditions on majority of the malting quality traits has also been reported earlier (Briggs 1978, Henry and Johnston 1991, Verma and Nagarajan 1996).

The variance due to treatments for all malting quality traits revealed highly significant differences among genotypes (Table 1). The mean and range values revealed that wide variation for most of the traits (Table 2). The thin grain percentage, followed by malt friability and Kolbach index had higher values of GCV and PCV indicating that these traits are affected most by the environments/location (Table 2). For other traits relatively less fluctuation were observed and traits like hot water extract , bulk density, protein content and wort viscosity were stable across environments.

To optimize the levels of different quality traits for malting in barley cultivars is a complex problem as the selection for these traits is complicated by positive and negative correlations between the quality and agronomic characters (Briggs 1978). In the barley improvement programme, a clear understanding of the type and magnitude of association among different quality traits may be helpful for improving quality characters without losing yield. However very little information is available on genotypic and phenotypic correlation among different malting quality traits in barley. The genotypic and phenotypic correlations were estimated for each location as well as on pooled basis across 2 locations over 2 years. The results indicated that the correlation co-efficients were having similarity for majority of the traits over the 2 locations with few exceptions. Since the national barley improvement programme is intended for zonal or much wider basis and we are looking for association valid for such larger area the pooled data were used for calculation of correlation co-efficients (Table 3). Amongst the different traits hot water extract had highly significant correlation with hectolitre weight, proportion of bold grains, 1 000-grain weight, friability, homogeneity, filtration rate and Kolbach index, while it was showing significantly negative correlation with proportion of thin grains, protein content, husk content and viscosity. These observations were in accordance with earlier observations for some of traits (Briggs 1978). However no significant correlation could be observed between hot water extract with diastatic power in the present investigation, although positive correlation between hot water extract and diastatic power is reported earlier (Hayter and Riggs 1973, Henry 1989). The simple correlations among different malting quality traits have also been reported by Verma *et al*. (2008). The present results and earlier studies suggest that by making direct selection for easily measurable traits namely hectolitre weight, proportion of bold grain, 1 000-grain weight, direct improvement in hot water extract is possible to avoid a tedious process to measure hot water extract. Malt friability is another very important quality attribute, which predicts the modification of endosperm starch into simple sugars, mainly maltose during malting process. It is an important indicator of quality of malt and is easily measurable. On the other hand the biochemical analysis for traits like hot water extract, Kolbach index, wort viscosity and diastatic power requires tedious analytical procedures. The results in the present study indicate that malt friability had significant positive correlation with hectolitre weight, bold grain, 1 000-grain weight, homogeneity, wort filtration and Kolbach index. These associations are desirable from malting quality in barley. Incidentally it showed significant negative correlation with undesirable traits, like thin grain per cent, grain protein, husk content and wort viscosity for which lower values are required. The chances for overall quality improvements by making selection for malt friability are brighter.

Hectolitre weight, another important grain quality attribute measures the plumpness of the grain and is a good indicator of grain filling. Hectolitre weight showed significant positive correlation with grain plumpness, 1 000-grain weight, malt friability, homogeneity, wort filtration rate, Kolbach index and hot water extract. It also showed significant negative correlation with thin grain%, husk content and viscosity. Thus hectolitre weight can serve the purpose of selection at grain stage for ultimate malt quality improvement. In all, the significant genotypic and phenotypic correlation co-efficients were observed between 60 pairs of malting quality characters. Out of these, 35 showed positive while 25 showed negative association. Most of these correlation co-efficients represent desirable association among quality attributes from brewing quality point of view.

It can be concluded that selection for easily measurable traits like hectolitre weight, malt friability, 1 000-grain weight, percent bold grains along with yield and disease resistance will help in improvement of associated quality traits as well as the overall quality in malt barley breeding programme.

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