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Short Communication

Association of malting quality attributes under timely and late sown conditions in barley (*Hordeum vulgare* L.)

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Abstract

The present study was carried out to identify genetically associated physical grain and malting quality attributes, which are also exerting high direct effects on hot water extract under different sowing times in barley. The mean hot water extract was depicted as 78.69 and 80.33 per cents, which ranged from 70.20 to 84.00 and 75.40-82.80 per cents,under timely and late sown conditions, respectively. Average grain protein content and malt friability were exhibited as 11.66 and 46.29 per cents, which ranged from 9.40 to14.30 and 36.34-69.58 per cents, respectively under timely sown conditions. The hot water extract was found negatively correlated with grain protein content (r=-0.42* and -0.40*) under both the production conditions. Hectolitre weight, germinative energy, malt friability and diastatic power exerted high positive direct effects on hot water extract, whereas thin grains and protein content were revealed with negative direct effects under timely and late sown conditions.

Keywords: Correlation coefficient, path analysis, barley

1. Introduction

Barley is an ancient cereal crop and during 2012 occupied fourthrank (132.88 m t)after maize (872.06 m t), rice (719.73 m t) and wheat (670.87 m t) globally (FAOSTAT, 2014;Kumar *et al.* 2014).Barley contributes 5.5-6% of the global cereals and 11.5-12% of the coarse cereals production (Baik and Ullrich, 2008; Kumar *et al.* 2013; Pal *et al.* 2012). Barley grain is used mainly for feed but with time and changing economy also gaining importance for food (multi-grains) and malting purposes. Among cereals, barley is most preferred for malt, as its husk protects the coleoptile during germination and provides aid in filtration, firm texture of grains and its amylase activity makes it unique for malt recovery. The utilization of barley for malting and brewing industry has picked up recently with an increase of consumption of beer, health drinks and other malt based products in India.

Barley is favourable crop for marginal and small farmers due to its low nutrient and water requirement, better adaptability to harsh environments and comparatively short life cycle makes fit in different crop rotations *i.e.* paddy, pearl millet, sorghum, cotton etc. under timely and delayed sowings. Presence of new multi-national malting, brewing etc. companies in India and their contract farming schemes and procurement of barley as raw material is further triggered the demand of barley in the country. Hence, genetic enhancement of malt barley is crucial to deliver new technologies such as DWRUB52, DWRB73, DWRUB64, DWRB91, DWRB92 etc. with better physical and malting quality parameters of grain. Therefore, the present study was carried out to identify genetically associated grain and malting quality attributes which are also exerting high direct effectson hot water extract under different sowing times.

2. Materials and methods

During *rabi*, 2012-13, experiments were conducted at New Experimental Farm, Indian Institute of Wheat & Barley Research, Karnal with 30 malt barley advance strains and four checks viz. BH 902, DWRUB 52, DWRB 73 and DWRUB 64 under timely and late sown conditions. The timely and late experiments were sown on 12 Nov. 2013 and 10 Dec. 2013, respectively in arandomized complete block design (RCBD) with 4 replications. The processed grain samples were micro-malted as per standard cycle and data were recorded for five grain physical parameters *i.e.* 1000 grain weight (g), hectolitre weight (kg/hl), husk per cent, thin and bold grains per cents.The seven quality parameters namely grain protein content (% dry basis), malt yield (%), malt friability (%), hot water extract (%), germinative energy (%), wort filtration rate (ml/hr) and diastatic power (°Lintner) were also recorded. Grain protein content wasanalyzed using Near Infrared Reflectance (NIR) system, while diastatic power was estimated by Institute of Brewing (IOB) method. The rest of the biochemical parameters were recorded as per European Breweries Convention (EBC) procedure (Analytica-EBC, 2003). Correlation coefficients were computed as per standard methods (Singh and Chaudhary, 1985) and path coefficient analysis considering hot water extract as the resultant variable was carried out as per Dewey and Lu (1959).

3. Results and discussion

The characters studied depicted adequate variation for physical grain and malting quality attributes. The highest mean was observed for wort filtration rate (261.25 ml/hr), followed by diastatic power (109.72 °L), germinative energy (89.14%), malt yield (87.63%), bold grains (87.32%) etc. under timely sown conditions (Table 1).

Table 1. Mean and range of different malting quality parameters under timely and late sown conditions

Characters	Timely sown				Late sown			
	Mean	SE	Minimum	Maximum	Mean	SE	Minimum	Maximum
Germinative energy (%)	89.14	3.50	14.81	98.59	96.66	0.62	80.50	99.00
Bold grain (%)	87.32	2.41	30.60	98.90	86.35	2.58	31.20	99.30
Thin grain (%)	2.34	0.84	0.00	27.30	2.75	0.89	0.10	26.80
Husk (%)	9.24	0.19	7.00	12.10	10.33	0.19	7.50	13.70
Hectolitre weight (kg/hl)	66.93	0.52	55.50	71.20	68.70	0.36	61.80	72.10
1000 grain wt. (g)	48.00	1.08	30.80	61.20	47.71	0.88	27.90	57.70
Protein content (%)	11.66	0.24	9.40	14.30	12.85	0.25	10.40	16.30
Malt Friability (%)	46.29	2.62	36.34	69.58	52.54	1.43	33.90	65.00
Malt Yield (%)	87.63	0.62	77.10	96.20	87.48	0.54	76.30	91.90
Diastatic power (°L)	109.72	1.47	91.00	118.00	107.41	1.44	91.00	118.00
Wort filtration rate (ml/hr)	261.25	7.00	185.00	315.00	225.78	8.61	130.00	310.00
Hot water extract (%)	78.69	0.60	70.20	84.00	80.33	0.31	75.40	82.80

The average grain protein content, hot water extract and malt friability were exhibited as 11.66, 78.69 and 46.29 per cents, which ranged from 9.40 to 14.30, 70.20 to 84.00 and 36.34 to 69.58 per cents, respectively under timely sown conditions (Table 1). General means were observed high for bold grains, 1000 grain wt., malt yield, diastatic power and wort filtration rate under timely sown conditions, while germinative energy, hectolitre weight, grain protein content and hot water extract were exhibited with high *per se* under late sown conditions. The higher husk content coupled with more thin grains per cent was recorded under late sown conditions.

The highest significant positive correlation coefficient was depicted between hectolitre weight and germinative energy (r=0.71**) followed by r=0.70** (hot water extract and malt friability), r=0.69** (malt friability and germinative energy), r=0.67* (bold grains and hectolitre weight) etc. under timely sown conditions (Table 2).

Table 2. Correlation coefficients under timely and late sown conditions for different malting quality traits

Traits	Env.	DP	FR	Frb	GE	HWE	Hl	Husk	MY	Protein	TGW	Thin
Bold	TS	0.18	-0.16	0.28	0.48**	0.23	0.67**	-0.47	-0.23	0.24	0.47**	-0.88**
	LS	-0.23	0.03	0.05	0.29	-0.17	0.55**	-0.54**	0.10	0.24	0.72**	-0.94**
DP	TS		0.22	0.04	-0.05	0.14	0.17	0.08	-0.09	-0.02	0.13	-0.03
	LS		0.12	0.19	-0.16	0.16	-0.34*	0.07	-0.23	-0.10	-0.14	0.17
FR	TS			-0.06	-0.24	-0.06	-0.19	0.12	-0.31	0.44*	-0.20	0.24
	LS			0.23	-0.17	-0.08	-0.04	-0.29	-0.31	-0.04	-0.08	0.01

Traits	Env.	DP	FR	Frb	GE	HWE	Hl	Husk	MY	Protein	TGW	Thin
Frb	TS				0.69**	0.70**	0.23	-0.23	-0.55*	-0.14	0.30	-0.29
	LS				0.06	0.25	0.06	-0.07	-0.40*	-0.28	-0.17	0.02
GE	TS					0.65**	0.71**	-0.40*	-0.37	-0.08	0.33	-0.64*
	LS					0.06	0.03	0.13	-0.16	0.10	0.10	-0.18
HWE	TS						0.35*	-0.08	-0.41*	-0.42*	0.26	-0.32
	LS						0.21	0.13	-0.22	-0.40*	0.01	0.10
Hl	TS							-0.44*	-0.20	0.13	0.31*	-0.73**
	LS							-0.58**	0.32	-0.09	0.60**	-0.66**
Husk	TS								0.27	-0.14	-0.25	0.55**
	LS								-0.25	-0.19	-0.48**	0.61**
MY	TS									-0.26	-0.07	0.20
	LS									0.22	0.26	-0.12
Prot	TS										-0.15	-0.12
	LS										0.20	-0.24
TGW	TS											-0.50**
	LS											-0.76**

**Bold-bold grains (%), DP-diastatic power (°L), FR-wortfiltration rate (ml/hr), Frb-malt friability (%), GE-germinative energy (%), HWE-hot water extract (%), Hl-hectolitre weight (kg/hl), Husk- husk (%), MY-malt yield (%), Prot-grain protein content (%), TGW-1000 grain weight (g), Thin-thin grain (%)*

For late sown conditions the highest significant positive correlation coefficient was exhibited between bold grains and 1000 grain weight (0.72**) followed by 0.61** (thin grains and husk content), 0.60** (1000 grain weight and hectolitre weight) etc. The bold grains were found correlated with hectolitre weight and 1000 grain weight and as well as hectolitre weight and 1000 grain weight were found significantly associated under timely and late sown conditions. The hot water extract was found negatively correlated with protein content under both production conditions. Similar correlations for malting quality traits have been also observed by Sarkar *et al.* 2008 and Verma *et al.* 2008.

Hot water extract is the main objective in malt barley improvement programme and is a complex quantitative trait resultant of linear and multiplicative interaction of its various causal factors. The relationships obtained by path analysis for timely sown conditions suggested that the highest positive direct effects were exhibited by malt friability (0.351) followed by germinative energy (0.246), wort filtration rate (0.212) etc. on hot water extract (Table 3).

Table 3. Direct and indirect effects of malting quality parameters on hot water extract

Characters	Env.	Hl	Bold	Thin	TGW	Husk	Protein	GE	MY	Frb	FR	DP
Hl	TS	0.149	0.013	0.095	-0.018	-0.078	-0.066	0.175	0.036	0.081	-0.040	0.005
	LS	0.526	-0.292	0.038	0.133	-0.089	0.016	0.005	-0.075	0.008	0.003	-0.060
Bold	TS	0.100	0.020	0.114	-0.027	-0.082	-0.125	0.119	0.042	0.100	-0.034	0.005
	LS	0.290	-0.530	0.055	0.160	-0.082	-0.041	0.038	-0.023	0.006	-0.003	-0.041
Thin	TS	-0.109	-0.017	-0.129	0.029	0.097	0.062	-0.158	-0.036	-0.102	0.050	-0.001
	LS	-0.345	0.499	-0.058	-0.170	0.093	0.043	-0.023	0.028	0.002	-0.001	0.030
TGW	TS	0.046	0.009	0.065	-0.058	-0.045	0.078	0.082	0.013	0.106	-0.043	0.003
	LS	0.315	-0.381	0.044	0.222	-0.074	-0.035	0.013	-0.062	-0.020	0.008	-0.025
Husk	TS	-0.066	-0.009	-0.071	0.015	0.177	0.071	-0.099	-0.050	-0.081	0.026	0.002
	LS	-0.307	0.284	-0.035	-0.107	0.152	0.033	0.018	0.060	-0.008	0.026	0.012
Protein	TS	0.019	0.005	0.016	0.009	-0.025	-0.512	-0.020	0.048	-0.048	0.092	0.000
	LS	-0.047	-0.125	0.014	0.044	-0.029	-0.175	0.013	-0.053	-0.034	0.003	-0.017
GE	TS	0.106	0.010	0.083	-0.019	-0.071	0.041	0.246	0.068	0.242	-0.051	-0.001
	LS	0.018	-0.154	0.010	0.022	0.021	-0.017	0.130	0.039	0.007	0.015	-0.028

Characters	Env.	Hl	Bold	Thin	TGW	Husk	Protein	GE	MY	Frb	FR	DP
MY	TS	-0.029	-0.005	-0.026	0.004	0.048	0.133	-0.091	-0.184	-0.192	-0.066	-0.002
	LS	0.167	-0.051	0.007	0.058	-0.039	-0.039	-0.021	-0.238	-0.048	0.028	-0.041
Frb	TS	0.034	0.006	0.038	-0.017	-0.041	0.070	0.170	0.101	0.351	-0.014	0.001
	LS	0.034	-0.026	-0.001	-0.037	-0.010	0.050	0.008	0.095	0.120	-0.021	0.035
FR	TS	-0.028	-0.003	-0.030	0.012	0.021	-0.223	-0.059	0.057	-0.022	0.212	0.006
	LS	-0.020	-0.018	-0.001	-0.019	-0.044	0.007	-0.022	0.074	0.028	-0.089	0.021
DP	TS	0.026	0.004	0.003	-0.007	0.014	0.009	-0.012	0.017	0.015	0.047	0.027
	LS	-0.177	0.122	-0.010	-0.032	0.010	0.017	-0.020	0.054	0.023	-0.010	0.178

Under late sown conditions the traits *viz.* hectolitre weight (0.526), 1000 grain weight and diastatic power (0.178) depicted high positive direct effects on hot water extract. After perusal of data in Table 3 it was observed that the quality parameters namely hectolitre weight, germinative energy, malt friability and diastatic power exerted high positive direct effects on hot water extract, while thin grains and protein content were found with negative direct effects for hot water extract under both the production conditions. Molina-Cano *et al.* 1997 also reported similar findings for hot water extract and protein content association. The residual effects were exhibited as 0.24 and 0.58 for timely and late sown conditions, respectively and suggested for the incorporation of some more quality attributes under late sown conditions.

Therefore, it can be concluded that the direct selection under timely and late sown conditions for the attributes *viz.* hectolitre weight, germinative energy and diastatic power would be regarded as reliable and efficient characters as these parameters exerted high direct effects and also exhibited the positive correlations with hot water extract. Protein content revealed negative correlation with hot water extract with negative direct effects, thus indicating restriction selection model for the trait in malt barley improvement. The other important malting quality attributes *viz.* wort filtration rate and malt yield would also beuseful parameters and indicated simultaneous indirect selection for high hot water extract.

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