

## Correlation and path coefficient analysis for malting quality traits under varying sowing dates in barley (*Hordeum vulgare* L.)

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### Abstract

The present study was conducted to delineate association of malting quality traits under timely and late sown conditions in barley. General mean for test weight, 1000 grain weight, grain protein content and hot water extract were exhibited as 60.09 kg/hl, 44.57 g, 11.57 and 79.78 per cents, respectively under timely sown conditions. Average diastatic power and FAN content were depicted as 107.90 °L and 178.72 ppm, under late sown conditions. The traits averages for test weight, bold grains, 1000 grain weight, protein content and FAN content were higher under late sown conditions, due to prolonged grain filling period under congenial climatic conditions. Hot water extract found negatively associated with grain protein (-0.27 and -0.48) and FAN content (-0.15 and -0.27), while positively associated with Kolbach index (0.16 and 0.47) under both the sowing conditions. The quality characters namely test weight and Kolbach index exhibited positive direct effects, while grain protein content, wort filtration rate and FAN content depicted negative direct effects on hot water extract under timely and late sown conditions. Therefore, for better malting quality direct selection for the grain physical parameters viz. test weight and bold grains, while restriction selection model for protein and FAN contents is suggested under timely and late planting dates.

## 1. Introduction

Barley is an ancient coarse cereal crop of poor man being used for food, malt and feed purposes (Baik and Ullrich, 2008). Barley thrives well in adverse climatic conditions *i.e.* drought and salinity (Kumar *et al.*, 2014). Barley is one of the key crops of small and marginal farmers for ensured remunerative under challenges like global warming, abiotic stresses and climate vagaries. Barley malting quality depends upon different attributes *i.e.* test weight, bold grains, protein content, diastatic power, filtration rate, malt extract etc (Fox *et al.*, 2003). Practices of plant breeding have led to the development of several high yielding varieties with disease resistance and good malting quality. However, malting quality characters are of polygenic nature and narrow genetic base and changed disease and pest dynamics further aggravates the situation for grain yield and quality improvement (Lapitan *et al.*,

2009). Therefore, barley being self-pollinated crop, the information on association of malting quality traits is greatly needed to define selection criteria and to obtain better end quality. Correlation coefficients describe associations among independent characters and delineate the direction of varied relationship. In addition, path analysis further clarifies the relationship by separating direct and indirect effects by partitioning the correlation coefficient. Association studies of malting quality attributes are not so extensive in India and have been reported by Bichonski and Smialowski, 2004; Bao *et al.*, 2010; Przulj *et al.*, 2013 from global parts. Therefore, the present study was carried out to identify association of malting and brewing quality attributes and further refinement of associations by path coefficients under timely and late sown conditions in barley.

## 2. Materials and methods

During *rabi*, 2014-15, experiment was conducted at New Experimental Farm, ICAR-Indian Institute of Wheat & Barley Research, Karnal with 31 malt barley advance strains with two checks viz. BH 946 and DWRB92 under timely sown and BH946 and DWRB91 under late sown conditions. The timely and late experiments were sown on 16 Nov. 2014 and 10 Dec. 2014, respectively in randomized complete block design (RCBD) with 3 and 4 replications, respectively. The processed grain samples were micro-malted as per standard cycle and data were recorded for three grain physical parameters i.e. test weight (kg/hl), 1000 grain weight (g), and bold grains per cents. The six quality parameters namely grain protein content (% dry wt. basis), hot water extract (%), wort filtration rate (ml/hr), diastatic power ( $^{\circ}$ Lintner), Kolbach index (%) and free amino nitrogen (ppm) were also recorded. Grain protein content was analyzed 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. Result and discussions

The quality characters studied depicted adequate variation for physical grain and malting quality traits. The highest mean was observed for wort filtration rate (266.36 ml/hr), followed by FAN content (167.74 ppm), diastatic power (107.12  $^{\circ}$ L) and bold grains (81.58%) under timely sown conditions (Table 1)

**Table 1.** *Per se* performance and range of quality parameters under timely and late sown conditions

Characters	Timely sown			Late sown		
	Mean	SE	Range	Mean	SE	Range
Test wt (kg/hl)	60.09	0.49	52.70-67.60	62.88	0.45	55.90-73.20
Bold grain (%)	81.58	1.77	24.50-98.30	89.02	1.82	47.60-99.50
1000 grain wt. (g)	44.57	0.97	30.80-55.80	50.6	0.98	36.30-64.10
Protein (% dwb)	11.57	0.51	8.70-15.20	12.41	0.42	9.80-15.20
HWE (% dfgb)	79.78	0.42	71.60-85.90	79.23	0.27	73.90-82.70
Filtration rate (ml/hr)	266.36	2.11	195.00-325.00	209.24	4.13	110.00-300.00
Diastatic power ( $^{\circ}$ L)	107.12	0.81	88.90-121.20	107.9	0.82	88.90-121.20
Kolbach index (%)	38.52	0.3	33.60-41.10	37.83	0.2	34.90-40.60
FAN (ppm)	167.74	2.05	120.20-237.00	178.72	1.75	127.50-210.00

The average test weight, 1000 grain weight, grain protein content and hot water extract were exhibited as 60.09 kg/hl, 44.57 g, 11.57 and 79.78 per cents, respectively under timely sown conditions, whereas, general mean for wort filtration rate, FAN content and diastatic power were revealed as 209.24 ml/hr, 178.72 ppm and 107.90 $^{\circ}$ L under late sown conditions (Table 1). In general, the traits averages were higher for all the quality characters under late sown conditions, except filtration rate and Kolbach index, while hot water extract and diastatic power were similar for *per se* under both timely and late sown conditions. During *rabi*, 2014-15, the received precipitation of nearly 247mm in different spells led to congenial temperature during grain filling stage under late sown conditions. However, an excessive lodging was also observed with low grain yield under timely

sown conditions. As reported by Kumar *et al.* 2015 (c), the relatively cool climatic conditions for starch biosynthesis enzyme ADP-glucose pyrophosphorylase (AGPase) during grain filling stage may be the reason for good quality attributes under late sown conditions. The highest significant positive correlation coefficient was depicted between bold grains and 1000 grain weight (0.64\*\*) followed by grain protein and FAN content (0.40\*), test weight and 1000 grain weight (0.36\*) and diastatic power and filtration rate (0.36\*) under timely sown conditions. Under late sown conditions the highest correlation coefficient was obtained between hot water extract and Kolbach index (0.47\*\*) followed by bold grains and FAN content (0.44\*\*) and filtration rate and FAN content (0.41\*) (Table 2).

**Table 2.** Correlation coefficients of quality traits under timely and late sown conditions

Traits	Env.	Bold grain	1000 grain wt.	Protein content	HWE	Filtration rate	Diastatic power	Kolbach index	FAN content
Test wt	TS	0.25	0.36*	0.07	-0.14	0.01	-0.17	-0.29	-0.07
	LS	0.03	0.15	0.12	0.05	0.17	0.18	-0.07	-0.13
Bold grain	TS	-	0.64**	0.09	-0.25	0.23	0.18	-0.14	-0.16
	LS	-	0.32	0.06	-0.11	0.34	-0.21	-0.07	0.44**
1000 grain wt.	TS	-	-	0.27	-0.51**	-0.3	-0.19	-0.13	0.11
	LS	-	-	0.05	0.24	0.12	0.21	-0.07	0.22
Protein content	TS	-	-	-	-0.27	-0.19	-0.004	-0.31	0.40*
	LS	-	-	-	-0.48**	0.18	0.21	-0.35	0.19
HWE	TS	-	-	-	-	0.01	-0.04	0.16	-0.15
	LS	-	-	-	-	-0.47**	0.18	0.47**	-0.27
Filtration rate	TS	-	-	-	-	-	0.36*	0.09	-0.15
	LS	-	-	-	-	-	-0.08	-0.35*	0.41*
Diastatic power	TS	-	-	-	-	-	-	-0.06	-0.29
	LS	-	-	-	-	-	-	0.13	-0.15
Kolbach index	TS	-	-	-	-	-	-	-	0.11
	LS	-	-	-	-	-	-	-	-0.2

In general, the test weight showed positive correlations with bold grains, 1000 grain weight, grain protein and wort filtration rate under timely and late sown conditions. The hot water extract was found negatively associated with grain protein (-0.27 and -0.48) and FAN content (-0.15 and -0.27), while positively associated with Kolbach index under different sowing conditions. Grain protein content exhibited positive association with FAN content, while diastatic power depicted negative correlation coefficients with FAN content at varying sowing dates. These results

are in agreement with Kumar *et al.* 2015 (a) and Kumar *et al.* 2015 (b). The highest positive direct effects were exhibited by bold grains (0.39), Kolbach index (0.12) and test weight (0.09) in path analysis for hot water extract under timely sown conditions, whereas, under late sown conditions 1000 grain weight (0.29) followed by Kolbach index (0.21), diastatic power (0.11) and test weight (0.10) depicted high positive direct effects for hot water extract (Table 3). After perusal of data in Table 3 it was observed that the quality characters namely test weight and Kolbach

**Table 3.** Direct and indirect effects of malting and brewing traits on hot water extract

Characters	Env.	Test wt	Bold grain	1000 grain wt.	Protein content	Filtration rate	Diastatic power	Kolbach index	FAN	HWE
Test wt	TS	<b>0.095</b>	0.098	-0.316	-0.004	-0.004	0.027	-0.037	0.004	-0.14
	LS	<b>0.101</b>	-0.000	0.043	-0.047	-0.059	0.02	-0.015	0.005	0.05
Bold grain	TS	0.024	<b>0.394</b>	-0.559	-0.006	-0.072	-0.027	-0.017	0.01	-0.25
	LS	0.003	<b>-0.007</b>	0.094	-0.021	-0.118	-0.024	-0.015	-0.018	-0.11
1000 grain wt.	TS	0.034	0.251	<b>-0.877</b>	-0.019	0.094	0.029	-0.016	-0.007	-0.51**
	LS	0.015	-0.002	<b>0.292</b>	-0.02	-0.041	0.024	-0.015	-0.009	0.24
Protein content	TS	0.006	0.033	-0.238	<b>-0.07</b>	0.06	0.001	-0.039	-0.026	-0.27
	LS	0.012	-0.000	0.015	<b>-0.386</b>	-0.064	0.023	-0.076	-0.007	-0.48**
Filtration rate	TS	0.001	0.089	0.259	0.013	<b>-0.319</b>	-0.056	0.011	0.01	0.01
	LS	0.017	-0.002	0.034	-0.07	<b>-0.351</b>	-0.008	-0.075	-0.016	-0.47**
Diastatic power	TS	-0.016	0.069	0.165	0.000	-0.115	<b>-0.156</b>	-0.007	0.019	-0.04
	LS	0.017	0.001	0.061	-0.08	0.027	<b>0.113</b>	0.028	0.006	0.18
Kolbach index	TS	-0.028	-0.054	0.114	0.021	-0.028	0.009	<b>0.129</b>	-0.007	0.16
	LS	-0.007	0.001	-0.021	0.135	0.122	0.015	<b>0.216</b>	0.008	0.47**
FAN content	TS	-0.006	-0.063	-0.092	-0.028	0.048	0.045	0.014	<b>-0.067</b>	-0.15
	LS	-0.013	-0.003	0.064	-0.074	-0.142	-0.017	-0.042	<b>-0.041</b>	-0.27

Residuals-0.611 & 0.437

index exhibited positive direct effects, while grain protein content, filtration rate and FAN content depicted negative direct effects under both the production conditions. Molina-Cano *et al.*, 1997; Kumar *et al.*, 2015 (a), also reported similar findings for hot water extract and protein content association. The residual effects were exhibited as 0.61 and 0.43 for timely and late sown conditions, respectively and suggested for the incorporation of some more quality attributes under timely sown conditions.

Correlation and path analysis suggested that the grain protein and FAN contents were negatively associated with hot water extract. Both the traits also exerted negative direct effects upon hot water extract. In general, protein content from 9-12% (dry basis) is desirable for good brewing and malting. The higher protein may cause lower carbohydrate proportion resulting in to lower extract value, while the lower protein levels would also deteriorate quality by poor yeast amino nutrition. Kumar *et al.* 2015 (a) also emphasized that the optimum protein level is required for beer stability and to avoid chill haze formation. FAN content is measure of the individual wort amino acids and small peptides and required in desired concentration i.e. 150-200 ppm for good yeast growth and fermentation efficiency (Fox *et al.*, 2003). Besides, diastatic power is also an important parameter which collectively represents starch degrading enzymes namely,  $\alpha$ -amylase,  $\beta$ -amylase, limit dextrinase and  $\alpha$ -glucosidase (Kumar *et al.*, 2013). On the other hand the grain physical parameters are also equally important as test weight and 1000 grain weight. These grain parameters are indicators of kernel size, shape, plumpness, bold grains with starch content. Kolbach index depicted positive associations and direct effects on hot water extract, which is an indicator of degree of modification of protein during malting and mashing process.

Therefore, it can be concluded that grain protein content and FAN content showed negative correlations with hot water extract, while Kolbach index was positively associated under timely and late sown conditions. Test weight, bold grains and 1000 grain weight were interrelated with positive associations. Due to precipitation in different spells the malting traits were not deteriorated under late planting dates. However, filtration rate was lower under late sown conditions, while diastatic power and hot water extract were *at par* under timely sown conditions. Hence, it can be concluded that the seasons with adequate rainfall and low temperatures during grain filling are favourable for late sown barley crop and malting purposes. The direct selection for the grain physical traits viz. test weight and bold grains, while restriction selection

model for grain protein and FAN contents is suggested under timely and late sown conditions.

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