Original Research Article

Influence of sowing time on the quality and micronutrient contents of bread wheat (*Triticum aestivum* L)

.

ABSTRACT

Background: Wheat is a staple crop that feeds millions of people, but its productivity is significantly reduced under high temperatures. Maintaining grain quality under climate change is critical for human nutrition, end - use functional properties and commodity value. The current study aimed at assessing the quality and micronutrient contents under two environments for variability, correlation and path analysis.
Research Methodology: The research was carried in the experimental area of Wheat and Barley Section, Department of Genetics and Plant Breeding, CCSHAU, Hisar during 2019-20. The assessement was done for 48 wheat genotypes under two temperature levels (timely and late sown environment) in RBD design with three replications.
Results: Heat stress caused a significant reduction in grain yield, grain appearance score, hectoliter weight, sedimentation value, iron and zinc content whereas an increase in crude protein, total gluten content, wet gluten content, total soluble sugar. In the present study, total soluble sugar, wet gluten content, total gluten content showed highest values of variability, heritability, genetic advance as % of mean and thus are the most important quantitative traits to be taken into consideration for effective selection. A positive correlation was seen between grain yield and hectoliter weight in timely sown environment. Path analysis revealed highest positive direct effect for hectoliter weight and sedimentation value in timely sown condition while sedimentation value and iron content for late sown environment and thus in the process of selection much attention should be given to them as these characters are helpful for indirect selection.
Conclusion: A negative association between high yield and good quality should be an important target for the next breeding efforts or to determine a quality parameter that performs consistently in both environments.

Keywords: Correlation, micronutrients, path analysis, quality traits, variability, wheat.

1. INTRODUCTION

Wheat is a self-pollinating annual plant and is one of the rare crops being cultivated extensively around the world as a staple food source [1]. Breadwheat is grown across a wide range of agro-climatic zones and has been selected in part for a complex of various genes controlling the adaptive response. It comprises of "A" genome from the wild diploid (*Triticum urartu*), "B" genome most likely from (*Aegilops speltoides*), and "D"genome from (*Triticum tauschii*). It contains carbohydrate 78.10%, protein 14.70%, fat 2.10%, and some minerals such as zinc and iron [2]. Wheat is the largest source of cereal and vegetable protein in human food worldwide, having a higher protein content than maize and rice, the two other major kinds of cereal.

Micronutrient malnutrition affects over 2 billion people in the developing world. Zinc deficiency is among the top five micronutrient deficiencies and severely affects one-third of the world's population, especially rural communities [3]. The adoption of high-yielding cultivars of wheat seems to have aggravated the problem of malnutrition in humans [4]. Among micronutrient deficiency, Fe deficiency affects more than 2 billion people around the globe. Biofortification with zinc and iron improves the grain quality and yield of wheat crop [5]. It is vital that wheat grains possess desirable quality traits to serve the nutritional needs of the common masses and to tackle the problem of global malnutrition affecting 50% of the developing world's population. The All India Coordinated Wheat and Barley Research Improvement Project examines many traits related to marketability (grain appearance), industry (sedimentation value, crude protein, gluten content, hectoliter weight), grain micronutrient density (iron, zinc, and copper) and end-product usages (chapati, bread). Appearance is an important physical characteristic for selective classification and is the most important factor in determining economic value. In the milling industry, hectoliter weight is the most used physical quality parameter for cereals, as it is an estimate of bulk density. Weathering, shriveled or immature grains, as well as rain-induced field sprouting tend to reduce hectoliter weight [6]. The gluten content and bread-making properties of wheat ensure its relevance in society. The crude protein content and sedimentation value are also the most important indirect quality characteristics used in selecting quality wheat for early generation production.

Management practices such as planting date, seeding density, and cultivar cull play a very consequential role in determining the grain yield and culminate-use quality of bread wheat [7]. This study aims to assess quality traits, their variability, and correlation along with path coefficient analysis under two environments i.e timely and late sown.

2. METHODOLOGY

2.1 Experimental Material

The seed material used in the investigation comprised of 48 advance wheat breeding genotypes. The majority of the array consisted of genotypes from the 9th harvest plus yield trial (HPYT 403 to HPYT 437), along with that 2 black varieties (3818 Black, 3831 Black), 1 purple (3857 Purple), HPBW 01, PMBB 1, WB 2, DBW 187, WH 283, WL 711, WH 1127, WH 1136, WH 1252, HD 3226.

2.2 Layout of Field Experiments

The seed of all genotypes were grown in a Randomized Block Design (RBD) under timely sown (14 November) and late sown (18 December) conditions with three replications during (2019-20) at the research area of Wheat & Barley Section, Department of Genetics and Plant Breeding, CCS HAU, Hisar, India. The Research Farm Area is situated nearly 3.8 km away from the main campus and at about 29°10' N latitude and 75° 46' E longitude and an altitude of 228 m from sea level. Each plot consisted of 3 rows of 2 meters length and row to row distance was kept 20 cm in each replication. The soil was sandy loam in texture and had pH 8.1, mineral nitrogen 191.54 kg/ha, available phosphorous 17.25 kg/ha and available potassium 287 kg/ha. There is a canal system and subsurface water source (tube-well water) used for irrigation in Haryana. Approximately five irrigations were applied in each wheat environment.

2.3 Climate and Weather conditions

Hisar is located on the outer margins of the South-west monsoon region. It has semi-arid and subtropical climate with warm and dry winds during summer months, hot humid in monsoon and relatively cold dry weather in winter. Weather conditions during the *Rabi* season of 2019-20 was temperature in the range 12.7°C - 26.8°C and relative humidity 41-86% for timely sown environment whereas temperature range 6.1°C - 13.7°C and relative humidity 81 – 99% for the late sown environment.

2.4 Observations recorded

9 quality traits were analyzed. Grain appearance score (GA) is a subjective test and an important parameter in grain trade, for this grain size, shape, soundness, color and luster were collectively taken into consideration to judge the grain appearance score to 10 points. Hectoliter weight (HW) was determined by using the hectoliter weight instrument (Test weight instrument developed at DWR, Karnal) and values were expressed as kg per hectoliter. Sedimentation value (SV) in ml was calculated by Axford et al., [8] by using SDS/Lactic acid reagent (sodium dodecyl sulfate). Crude Protein (CP) in % was recorded by estimating total nitrogen in the sample by conventional Micro-kjeldahl's method. Total gluten content (TG) was calculated by adding wet gluten + dry gluten (%). Wet gluten was estimated by dough method i.e. flour sample of 10 g was taken in a clean dry beaker and 7 ml of distilled water was added. The contents were mixed by a glass rod to make a small ball of dough. It was then dipped into water for 30 minutes and then washed with the help of hands under the tap water until it becomes starch free. The gluten so obtained was weighed and then expressed in terms of percent wet gluten. The extracted wet gluten was oven-dried at 100°C for getting dry gluten.Total soluble sugar (TSS) in % was estimated by the method described by Dubois et al., [9]. Fe content (ppm) and Zn content (ppm) were calculated by AAS Spectrophotometer in parts per million.

2.5 Data analysis

Phenotypic and genotypic coefficient of variations, heritability in broad sense and genetic advance by Burton and Devane [10]. Correlation coefficient analysis by Al-Jibouri et al., [11] and path coefficient analysis by Dewey and Lu [12]. The data were subjected to statistical analysis using EXCEL, INDOSTAT and OPSTAT statistical software package which was developed by the Department of Statistics, CCS Haryana Agricultural University. The experimental data were analyzed using analysis of variance (ANOVA) technique following RBD design.

3. RESULTS AND DISCUSSION

3.1 Genetic parameters

Under both timely and late sown conditions, this has been demonstrated for several measures such as mean, range, coefficient of variation (GCV and PCV), broad sense heritability, and genetic advance as a percent of mean in [Table 1] for timely sown (TS) and [Table 2] for late sown environment (LS). Bar chart showing mean values with S.E of traits in both timely sown and late sown environments in Figure 1.

Normal environment produced significantly higher grain yield than late environment [13]. The mean values have been demonstrated to decrease for grain appearance score, hectoliter weight, sedimentation value, iron content, zinc content in the late sown environment, whereas the values increased for the remaining trait under heat stress. Delaying the sowing date resulted in a higher crude protein content due to high temperatures during grain filling, resulting in development of less leaf area which caused less interception of solar radiation and ultimately reduced photosynthate manufacturing and increased absorption of nitrogen by the crop because of the inverse relation between carbohydrates and nitrogen accumulation rate by the crop [14]. Micronutrient content also decreased under stress conditions because reduced grain and biomass yield at higher temperature resulted in lower micronutrient uptake of the crop. Our results are consistent with Amarshettiwar et al., [15], zinc and iron content significantly decreased under late sown condition as compared to timely sown condition.

GCV ranged from 2.75% (HW) to 26.43% (TSS) and 2.42% (HW) to 23.32% (TSS) under normal and late sown conditions respectively. The estimates of the phenotypic coefficient of variation varied from 3% (HW) to 26.88% (TSS) and 2.94% (HW) to 23.45% (TSS) under normal and late sown conditions respectively. Moderate GCV and PCV were obtained for sedimentation value, crude protein, total gluten content, wet gluten content, zinc content. On the contrary, Singh et al., [16] reported high GCV, PCV for sedimentation value. Mohan et al., [17] found that gluten properties such as sedimentation value and gluten content have moderate genetic variability (9-16%).

The estimates of heritability were higher for total soluble sugar, total gluten content, wet gluten content and sedimentation value. As Miko et al., [18] clearly describe in detail, the heritability of grain yield was lower than that of quality parameters. The estimates of genetic advance as % of mean were high for wet gluten content [34.73 (TS), 31.63 (LS)], total gluten content [32.10 (TS), 30.46 (LS)], sedimentation value [20.66 (TS), 21.49 (LS)]. High heritability and high genetic advance were recorded for sedimentation value, total gluten content, wet gluten content and total soluble sugar for both environments. Taneva et al., [19] found that sedimentation value has high heritability and considerable genetic advance, showing that an additive gene influence is dominant in affecting this trait and revealing the likelihood of successful selection. High heritability was linked to limited genetic advancement in hectoliter weight, highlighting the role of dominant and epistatic genes in the heritability of this trait and revealing slower breeding progress in their improvement. Moderate genetic advance and high heritability were seen for iron and zinc content, suggesting predominance of additive and non-additive gene action in the expression of this trait. Therefore, these traits can be improved by mass selection. Low heritability and genetic advance as % of mean were observed for hectoliter weight, grain appearance score, for both conditions, revealing that these traits were highly influenced by environment and selection would be ineffective for these characters.

Table 1. Genetic parameters for quality traits and micronutrient content in wheat under timely sown condition

Trait	Mean±S.E	Range		GCV	PCV	h^2 (bs)	GA as % mean
		Minimum	Maximum				
GA	5.45 ± 0.074	4.87	6.33	5.40	5.89	84.00	10.20
HW (Kg/hl)	77.79 ± 0.534	73.51	82.68	2.75	3.00	84.29	5.21
SV (ml)	41.66 ± 0.56	33.67	53.33	10.29	10.56	94.99	20.66
CP (%)	14.61 ± 0.55	11.34	20.13	10.88	12.68	73.57	19.21
TG (%)	35.59 ± 0.671	25.14	45.04	15.91	16.24	95.96	32.10
WG (%)	28.02 ± 0.686	19.93	36.06	17.36	17.87	94.37	34.73
TSS (%)	1.34 ± 0.038	0.84	2.43	26.43	26.88	96.71	53.55
Fe (ppm)	32.7 ± 0.674	26.33	38.30	7.90	8.66	83.19	14.84

Zn (ppm)	37.96 ± 0.894	29	44.97	10.20	10.99	86.22	19.52
GY (g)	15.01 ± 0.741	11.10	17.80	11.20	14.09	63.23	18.35

GA= Grain appearance score, HW= Hectoliter weight (Kg/hl), SV= Sedimentation value (ml), CP= Crude protein (%), TG= Total gluten content (%), WG= Wet gluten content (%), TSS= Total soluble sugar (%), Fe= Iron content (ppm), Zn= Zinc content (ppm), GY= Grain yield/plant (g)

Table 2. Genetic parameters for quality traits and micronutrient content in wheat under late sown condition

Trait	Mean±S.E	Range		GCV	PCV	h^2 (bs)	GA as % mean
		Minimum	Maximum				
GA	5.32 ± 0.093	4.73	6.27	5.14	5.96	74.46	9.14
HW (Kg/hl)	76.65 ± 0.74	72.71	81.47	2.42	2.94	67.76	4.11
SV (ml)	39.49 ± 0.854	31.67	51.67	11.02	11.64	89.64	21.49
CP (%)	17.08 ± 0.441	12.49	20.78	10.58	11.67	82.27	19.78
TG (%)	44.78 ± 0.553	33.08	58.56	14.94	15.09	98.00	30.46
WG (%)	33.67 ± 0.908	24.34	45.80	16.00	16.66	92.14	31.63
TSS (%)	1.63 ± 0.024	1.04	2.77	23.32	23.45	98.85	47.76
Fe (ppm)	30.29 ± 0.786	24.93	35.47	7.70	8.92	74.62	13.71
Zn (ppm)	33.89 ± 1.104	26.13	40.80	11.23	12.57	79.86	20.68
GY (g)	13.55 ± 0.772	8.50	16.27	13.33	16.59	64.57	22.07

GA= Grain appearance score, HW= Hectoliter weight (Kg/hl), SV= Sedimentation value (ml), CP= Crude protein (%), TG= Total gluten content (%), WG= Wet gluten content (%), TSS= Total soluble sugar (%), Fe= Iron content (ppm), Zn= Zinc content (ppm), GY= Grain yield/plant (g)

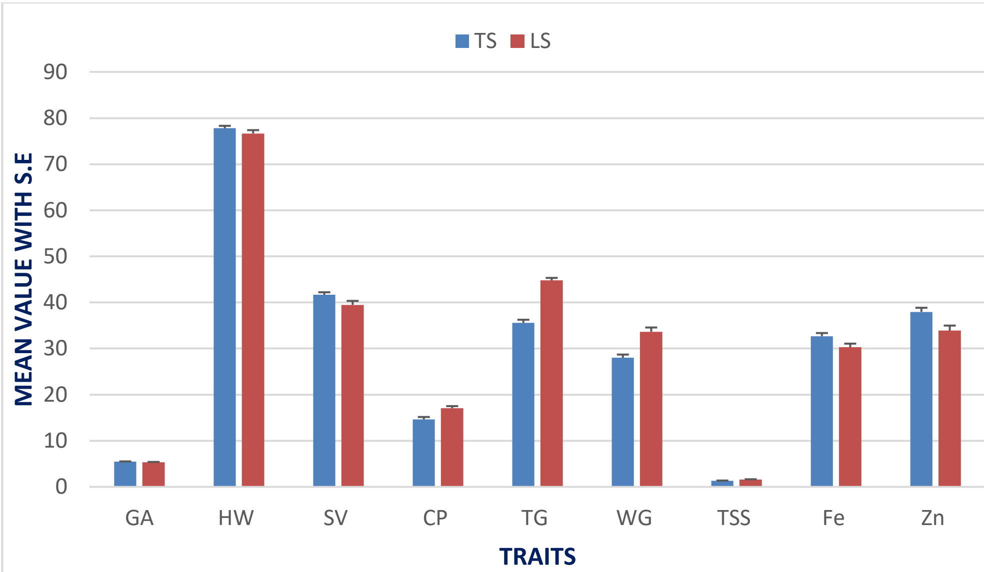

Figure 1. Bar chart showing mean values with S.E of traits in both timely sown and late sown environments

GA = Grain appearance score, HW = Hectoliter weight (Kg/hl), SV = Sedimentation value (ml), CP = Crude protein (%), TG = Total gluten content (%), WG = Wet gluten content (%), TSS = Total soluble sugar (%), Fe = Iron content (ppm), Zn = Zinc content (ppm), GY = Grain yield/plant (g), TS = Timely sown, LS = Late sown, S.E= Standard error.

3.2 Correlation

A correlation coefficient is a numerical measure of a statistical relationship between two variables. By using indirect selection for component traits, yield can be improved by correlating yield with component traits. It is shown in [Table 3] and [Table 4] for timely and late sown conditions.

Under both environments, grain yield exhibited a negative and significant correlation with wet gluten content. Total gluten content exhibited a positive significant correlation with wet gluten content. Mohan and Gupta [20] reported that the correlation between grain yield and wet gluten was negative and highly significant. Grain yield exhibited a positive correlation with hectoliter weight (0.187) and a negative correlation with total gluten content (-0.212) for timely sown condition. All the remaining traits had non significant correlation with grain yield. Zinc and iron content were positively correlated with each other whereas no correlation with grain yield. Zinc content exhibited a positive and significant correlation with iron content, crude protein, whereas negative correlation with wet gluten content and total soluble sugar. Iron content exhibited a negative correlation with total soluble sugar. Xu et al., [21] reported the results which agree with the findings of our study about positive correlation for Zn, Fe and protein concentration in wheat grain. Grain appearance score showed highly significant and a positive correlation with hectoliter weight [0.448 (TS), 0.264 (LS)] and total gluten content 0.168 (TS) whereas, negative correlation with crude protein [-0.247 (TS), -0.238 (LS)], iron content [-0.169 (TS), -0.193 (LS)] and zinc content -0.192 (TS). Previous investigations have indicated the same findings [22]. Crude protein content showed positive interrelation with zinc content [0.202 (TS), 0.173 (LS)], sedimentation value 0.164 (LS) and negative with total soluble sugar (- 0.383) for late sown environment. Hectoliter weight exhibited negative correlation with crude protein [-0.265 (TS), -0.289 (LS)], iron content - 0.188 (TS). Desheva et al., [23] reported a positive correlation for protein and sedimentation value; negative between crude protein and hectoliter weight.

Table 3. Phenotypic correlation coefficients (below diagonal values) and genotypic correlation coefficient (above diagonal values) among quality traits and micronutrient content of wheat under timely sown condition

	GA	HW	SV	CP	TG	WG	TSS	Fe	Zn	GY
GA		0.530**	-0.064	-0.361**	0.195*	-0.052	-0.074	-0.210*	-0.225**	-0.025
HW	0.448**		-0.048	-0.318**	0.131	0.003	0.060	-0.206*	-0.129	0.205*
SV	-0.043	-0.051		0.113	0.176*	0.165*	0.094	-0.009	-0.058	-0.017
CP	-0.247**	-0.265**	0.105		-0.086	0.035	-0.108	0.129	0.237**	-0.201*
TG	0.168*	0.120	0.164	-0.090		0.863**	-0.075	0.020	0.035	-0.268**
WG	-0.051	0.006	0.150	0.028	0.838**		0.045	-0.049	0.101	-0.247**
TSS	-0.080	0.067	0.085	-0.090	-0.069	0.046		-0.185*	-0.202*	-0.001
Fe	-0.169*	-0.188*	-0.010	0.065	0.009	-0.068	-0.177*		0.666**	-0.152
Zn	-0.192*	-0.102	-0.057	0.202*	0.037	0.092	-0.185*	0.564**		-0.088
GY	0.009	0.187*	-0.021	-0.132	-0.212*	-0.188*	-0.004	-0.109	-0.029	

** Significant at P = 0.05, ** Significant at P = 0.01*

GA = Grain appearance score, HW = Hectoliter weight (Kg/hl), SV = Sedimentation value (ml), CP = Crude protein (%), TG = Total gluten content (%), WG = Wet gluten content (%), TSS = Total soluble sugar (%), Fe = Iron content (ppm), Zn = Zinc content (ppm), GY = Grain yield/plant (g)

Table 4. Phenotypic correlation coefficients (below diagonal values) and genotypic correlation coefficient (above diagonal values) among quality traits and micronutrient content of wheat under late sown condition

	GA	HW	SV	CP	TG	WG	TSS	Fe	Zn	GY
GA		0.426**	-0.053	-0.339**	-0.082	-0.043	0.108	-0.290**	-0.089	-0.112
HW	0.264**		-0.110	-0.438**	0.031	-0.045	0.149	-0.093	0.006	0.099
SV	-0.033	-0.063		0.196*	0.076	0.052	0.064	0.007	-0.034	0.154
CP	-0.238**	-0.289**	0.164*		0.021	0.032	-0.428**	0.281**	0.234**	-0.095
TG	-0.065	0.016	0.066	0.006		0.953**	-0.050	-0.097	-0.178*	0.016
WG	-0.035	-0.066	0.029	0.002	0.924**		-0.016	-0.173*	-0.196*	-0.016
TSS	0.093	0.131	0.064	-0.383**	-0.048	-0.018		-0.444**	-0.480**	0.151
Fe	-0.193*	-0.052	-0.020	0.191*	-0.091	-0.150	-0.381**		0.619**	0.057
Zn	-0.107	-0.003	-0.027	0.173*	-0.154	-0.180*	-0.421**	0.485**		-0.075
GY	-0.061	0.099	0.150	-0.083	0.011	-0.033	0.120	0.041	-0.128	

** Significant at P = 0.05, ** Significant at P = 0.01*

GA= Grain appearance score, HW= Hectoliter weight (Kg/hl), SV= Sedimentation value (ml), CP= Crude protein (%), TG= Total gluten content (%), WG= Wet gluten content (%), TSS= Total soluble sugar (%), Fe= Iron content (ppm), Zn= Zinc content (ppm), GY= Grain yield/plant (g)

3.3 Path coefficient analysis

For quality traits, the highest positive and direct effect was seen for hectoliter weight (0.267), sedimentation value (0.071), zinc content (0.065), and the rest of the traits showed negative direct effects in timely sown environment. In late sown wheat, the highest positive direct effect was observed by sedimentation value (0.166), iron content (0.161), total soluble sugar (0.117), hectoliter weight (0.146), total gluten content (0.027) whereas, the rest of the traits showed negative direct effects. Phougat et al., [24] reported a high positive direct effect of sedimentation value on grain yield. Mecha et al., [25] observed contrary results of hectoliter weight. It is shown in [Table 5] and [Table 6] for timely and late sown environments respectively.

For timely sown wheat, hectoliter weight had an indirect positive effect on grain yield via iron content (0.036), crude protein (0.072), while indirect negative effect via remaining traits. Among all the studied traits, sedimentation value positive direct effect (0.071) was countered by the negative indirect effect of many resulting in a negative correlation coefficient (-0.017) so the traits governing this negative indirect effect should be kept in mind while deciding selection criteria for improvement. For wet gluten content, its direct effect was negative but small (-0.072), a significant upward trend was observed in this character due to major contribution by indirect negative effect by total gluten content (-0.201) resulting in correlation value which was -0.247. In the case of total soluble sugar, which had a negative direct effect, iron content, crude protein, contributed maximally through indirect effect whereas wet gluten content, zinc content had a highly negative effect. For micronutrient content (Fe and

Zn), the highest indirect positive effect was ruled by grain appearance score, whereas negative by crude protein and hectoliter weight. Zinc content path direct effect (0.065) was positive, but due to some traits such as hectoliter weight and crude protein which provided large indirect negative effect resulted in negative correlation value. Semnaninejad et al., [26] reported that the direct effect of wet gluten and total gluten on grain yield was negative, because starch accumulation increase due to photosynthesis and supply of assimilates caused reduction of fiber ratios in grain.

For late sown wheat, grain appearance score showed an indirect positive effect on grain yield via hectoliter weight, crude protein, wet gluten content, total soluble sugar, zinc content while indirect negative effect via iron content, sedimentation value, total gluten content. Hectoliter weight had the highest indirect positive effect on grain yield via two traits i.e crude protein and total soluble sugar while total gluten content (0.000) and wet gluten content (0.001) had a small but positive effect on grain yield and indirect negative effect via the remaining traits, the maximum value being shown by grain appearance score and sedimentation value. Sedimentation value showed the highest indirect positive effect on grain yield via grain appearance score, total soluble sugar, while highest indirect negative effect via crude protein, hectoliter weight. Shahin et al., [27] observed significant effects of protein percentage on sedimentation value. Crude protein path direct effect (-0.089) and correlation value (-0.095) was almost similar, revealing a true association between grain yield and this trait. Wet gluten content showed an indirect positive effect on grain yield via total gluten content, zinc content, grain appearance score, sedimentation value while indirect negative effect via remaining traits. Total soluble sugar showed an indirect negative effect on grain yield via three traits i.e iron content, grain appearance score, total gluten content, while positive indirect effect by most of the remaining traits. Among the micronutrients, both iron and zinc correlation was non significant with yield while their path direct effect was positive and negative respectively.

Table 5. Direct (diagonal) and indirect (off diagonal) effects of quality traits and micronutrient content on grain yield under timely sown condition

	GA	HW	SV	CP	TG	WG	TSS	Fe	Zn	GY (rg)
GA	**-0.232**	0.142	-0.004	0.082	-0.045	0.003	0.007	0.037	-0.014	-0.025
HW	-0.123	**0.267**	-0.003	0.072	-0.030	-0.000	-0.005	0.036	-0.008	0.205*
SV	0.014	-0.012	**0.071**	-0.025	-0.041	-0.012	-0.009	0.001	-0.003	-0.017
CP	0.083	-0.085	0.008	**-0.228**	0.020	-0.002	0.010	-0.022	0.015	-0.201*
TG	-0.045	0.035	0.012	0.019	**-0.233**	-0.062	0.007	-0.003	0.002	-0.268**
WG	0.012	0.000	0.011	-0.008	-0.201	**-0.072**	-0.004	0.008	0.006	-0.247**
TSS	0.017	0.016	0.006	0.024	0.017	-0.003	**-0.099**	0.032	-0.013	-0.001
Fe	0.048	-0.055	-0.000	-0.029	-0.004	0.003	0.018	**-0.176**	0.043	-0.152
Zn	0.052	-0.034	-0.004	-0.054	-0.008	-0.007	0.020	-0.117	**0.065**	-0.088

GA = Grain appearance score, HW = Hectoliter weight (Kg/hl), SV = Sedimentation value (ml), CP = Crude protein (%), TG = Total gluten content (%), WG = Wet gluten content (%), TSS = Total soluble sugar (%), Fe = Iron content (ppm), Zn = Zinc content (ppm), GY = Grain yield/plant (g)

Table 6. Direct (diagonal) and indirect (off diagonal) effects of quality traits and micronutrient content on grain yield under late sown condition

	GA	HW	SV	CP	TG	WG	TSS	Fe	Zn	GY (rg)
GA	**-0.171**	0.062	-0.008	0.030	-0.002	0.001	0.012	-0.046	0.009	-0.112
HW	-0.073	**0.146**	-0.018	0.039	0.000	0.001	0.017	-0.015	-0.000	0.099
SV	0.009	-0.016	**0.166**	-0.017	0.002	-0.002	0.007	0.001	0.003	0.154
CP	0.058	-0.064	0.032	**-0.089**	0.000	-0.001	-0.050	0.045	-0.026	-0.095
TG	0.014	0.004	0.012	-0.001	**0.027**	-0.038	-0.005	-0.015	0.019	0.016
WG	0.007	-0.006	0.008	-0.002	0.025	**-0.040**	-0.001	-0.027	0.021	-0.016
TSS	-0.018	0.021	0.010	0.038	-0.001	0.000	**0.117**	-0.071	0.053	0.151
Fe	0.049	-0.013	0.001	-0.025	-0.002	0.007	-0.052	**0.161**	-0.069	0.057
Zn	0.015	0.000	-0.005	-0.021	-0.004	0.007	-0.056	0.100	**-0.111**	-0.075

GA = Grain appearance score, HW = Hectoliter weight (Kg/hl), SV = Sedimentation value (ml), CP = Crude protein (%), TG = Total gluten content (%), WG = Wet gluten content (%), TSS = Total soluble sugar (%), Fe = Iron content (ppm), Zn = Zinc content (ppm), GY = Grain yield/plant (g)

4. CONCLUSION

Wheat is an important source of energy, protein, and dietary fiber for humans. The climate is changing, however, and this threatens our wheat harvests and the quality of food. Sedimentation value, total gluten content and wet gluten content were found to have high genetic advance and high heritability for both environments, suggesting an additive gene component is dominant in affecting this trait. The highest positive and direct effect was seen for hectoliter weight and sedimentation value, zinc content in timely sown environment. In late sown wheat, sedimentation value, iron content, total soluble sugar showed high path direct effects in descending order, suggesting that these should be the main factors in the quality selection.The simultaneous improvement of grain yield with wet gluten and total gluten content was seen as a major challenge due to the negative interrelationship. As respect to genotypes, HPBW 01 performed good in timely sown condition whereas HPYT – 415 in late sown condition respectively. Considering future scope, we must be on the lookout for a negative correlation between high yield and quality in our next breeding efforts or to determine a quality parameter that performs consistently in both environments.

REFERENCES

1. Mollasadeghi V, Shahryari R. Important morphological markers for improvement of yield in bread wheat. Adv Environ Biol. 2012; 5(3): 538-542.

2. Rizwani GH, Abbas K, Zahid H. Prevention and treatment of different health problems by common peopleâ€™s diet (Haleem). Afr. J. Food Sci. 2017; 11(4): 82-94.

3. Hotz C, Brown KH. Assessment of the risk of zinc deficiency in populations and options for its control. Food Nutr Bull. 2014; 25: 94-204.

4. Stein AJ. Global impacts of human mineral malnutrition. Plant and Soil. 2010; 335: 133-154. doi: https://doi.org/10.1007/s11104-009-0228-2

5. Ramzan Y, Hafeez MB, Khan S, Nadeem M, Rahman S. Biofortification with Zinc and Iron Improves the Grain Quality and Yield of Wheat Crop. Int J Plant Prod. 2020; 14(3): 501–510. doi: https://doi.org/10.1007/s42106-020-00100-w

6. Donelson JR, Gaines CS, Andrews LC, Finney PF. Prediction of test weight from a small volume specific gravity measurement. Cereal Chem. 2002; 79(2): 227-229. doi: 10.1094/CCHEM.2002.79.2.227

7. Yadi R, Ebrahimi M, Dastan S. Effect of seed rate in different sowing dates on grain yield and yield components of wheat in Iran. Int. J. Trop. Med. 2016; 11(6): 208-213.

8. Axford DWE, Mc-Dermott EE, Redman DG. Note on SDS-sedimentation test and bread making quality: Comparison with pelshenke and zeleny-tests. Cereal Chem. 1979; 56: 582-584.

9. Dubois M, Gilles KA, Hamilton JJ, Rubress PA, Smith F. Colorimetric method for determination of sugar and related substances. Anal. Chem. 1956; 28(3): 350- 356.

10. Burton UCW, Devane EH. Estimating heritability in tall Festuca (*Festuca arundinacea*) from donar material. Agron. J. 1953; 45(10): 1476-1481. doi: https://doi.org/10.2134/agronj1953.00021962004500100005x

11. Al-Jibouri HA, Miller PA, Robinson HF. Genotypic and environmental variation and correlation in upland cotton cross of interspecies origin. Agron. J. 1958; 50(10): 633-637. doi: https://doi.org/10.2134/agronj1958.00021962005000100020x

12. Dewey DR, Lu KH. A correlation and path coefficient analysis of components crested wheat grass and seed production. Agron. J. 1959; 51(9): 515-518. doi: https://doi.org/10.2134/agronj1959.00021962005100090002x

13. Shirpurkar GN, Kashid NV, Pisal AA. Effect of different sowing dates and varieties on yield and yield attribute of wheat. Agric. Sci. Digest. 2007; 27(1): 68-70.

14. Subedi KD, Ma BL, Xue AG. Planting date and nitrogen effects on grain yield and protein content of spring wheat. Crop Sci. 2007; 47(1): 36-44. doi: https://doi.org/10.2135/cropsci2006.02.0099

15. Amarshettiwar SB, Berad PB, Potdukheo NR. Sowing time and genotypes effects on micronutrient contents of wheat grain. J Pharmacogn Phytochem. 2018; 7(2): 44-47.

16. Singh M, Mishra DK, Shukla RS, Samaiya RK. Variation and heritability for some quality characteristics and grain yield in bread wheat (*Triticum aestivum* L.). Trends Biosci. 2015; 8(1): 68 -70.

17. Mohan D, Gupta RK, Verma A. Characterization of popular bread wheat cultivars of India for grain quality and the stable genetic resource. Indian J Genet Plant Breed. 2013; 73(1): 14-22. doi: 10.5958/j.0019-5200.73.1.002

18. Miko P, Loschenberger F, Hiltbrunner J, Aebi R, Megyeri M. Comparison of bread wheat varieties with different breeding origin in different management systems. Euphytica. 2014; 199: 69-80. doi: 10.1007/s10681-014-1171-8

19. Taneva K, Bozhanova V, Petrova I. Variability, heritability and genetic advance of some grain quality traits and grain yield in durum wheat genotypes. Bulg. J. Agric. Sci. 2019; 25(2): 288–295.

20. Mohan D, Gupta RK. Relevance of physiological efficiency in wheat grain quality and the prospects of improvement. Physiol Mol Biol Plants. 2015; 21(4): 591–596. doi: 10.1007/s12298-015-0329-8

21. Xu Y, An D, Liu D, Zhang A, Xu H. Molecular mapping of QTLs for grain zinc, iron and protein concentration of wheat across two environments. Field Crops Res. 2012; 138(5): 57–62. doi:10.1016/j.fcr.2012.09.017

22. Morgounov A, Gomez-Becerra HF, Abugalieva A, Dzhunusova M, Yessimbekova M. Iron and zinc grain diversity in common wheat grown in central Asia. Euphytica. 2007; 155(1): 193-203. doi: 10.1007/s10681-006-9321-2

23. Desheva G, Kyosev B, Sabeva M, Deshev M. Genetic variation of gliadins and some quality characteristics in spelt wheat. Bulg. J. Agric. Sci. 2021; 27(3): 541–554.

24. Phougat D, Panwar IS, Saharan RP, Singh V, Godara A. Genetic diversity and association studies for yield attributing traits in bread wheat [*Triticum aestivum* (L.) em. Thell]. Res. 2017; 18(1): 139-144. doi: 10.5958/2348-7542.2017.00024.9

25. Mecha B, Alamerew S, Assefa A, Dutamo D, Assefa E. Correlation and path coefficient studies of yield and yield associated traits in bread wheat (*Triticum aestivum* L.) genotypes. Adv. plants agric. res. 2017; 6(5): 226 - 228. doi: 10.15406/apar.2017.06.00226

26. Semnaninejad H, Nourmohammadi G, Rameeh V, Cherati A. Correlation and path coefficient analyses of phenological traits, yield components and quality traits in wheat. Revista Brasileira de Engenharia Agrícola e Ambiental. 2021; 25(9): 597-603. doi: https://doi.org/10.1590/1807-1929/agriambi.v25n9p597-603

27. Shahin F, Nia F, Rezaei A, Saedi A. Variation and path coefficient analysis of bread making quality traits in breeding lines, cultivars and landrace varieties of wheat. J. Water Soil Sci. 2002; 6(2): 77-89.