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Association analysis for yield attributing traits and micronutrients content in F_2 population of wheat (*Triticum aestivum* L.)

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Abstract
The present study was undertaken with the objective to detect an association between the yield attributing traits and micronutrients content in F_2 population obtained from two crosses namely cross- I (HPYT 461 × HD 2733) and cross-II (BHU 31 × HD 2967) in wheat for identifying high yielding and high micronutrients containing lines. The two F_2 populations obtained from these crosses (made in *Rabi* 2018) were evaluated for 13 quantitative traits including yield and micronutrient traits during *Rabi* 2020 in compact family block design with 3 replications at Research farm, RPCAU, Pusa and data were recorded on individual plant basis on fifty plants per replication of each cross for all the traits. The estimation of micronutrient in wheat grains was done by X-Ray Fluorescence Spectrometry at Harvest-plus Division, ICRISAT, Hyderabad. The analysis of association between the grain yield and micronutrient content was established through correlation and path analysis. In both the F_2 population grain yield per plant exhibited significant and positive phenotypic and genotypic correlation with harvest index and positive and significant genotypic correlation with spike length. Further, a negative correlation was observed between grain yield and grain Zinc and Iron content while the latter have positive correlation among themselves. The phenotypic path matrix in both the cross showed that number of grains per spikes, harvest index, spike length, number of tillers per plant, days to maturity and days to 50 per cent flowering have direct positive effect on yield while grain Zinc content, grain Iron content and chlorophyll content have direct negative effect on yield.

Keywords: Wheat, grain yield, grain zinc content, grain iron content, x-ray fluorescence spectrometry

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple food crop in world that fulfill nearly 20% of global daily food requirement (Reynolds *et al.*, 2012) [15]. It is the 2nd most important food crop after rice in India contributing nearly 1/3rd of the total food grain production and has been described as the stuff of life or king of the cereals for centuries. In India, wheat is cultivated over an area of 30.5 million hectares with a production of 107.2 million tons and average productivity of 3.51 t/ha (Annual Report, 2019-2020, DAC&FW) [20]. In countries, where it is a staple crop, wheat based diet provide 20 per cent of the total protein & 40 per cent of dietry intake of essential micronutrient, including Zinc, Iron, Manganese and vitamins B & E (Velu 2017) [16]. However, from the beginning of 21st centuries a number of cases of micronutrient malnutrition or hidden hunger, arising due Zn & Fe deficiency has been reported. As per UNSSC 2004 [21], estimate it ails over 3 billion people worldwide & over 2 billion people are facing this malnutrition in acute form (WHO 2017) [17]. To combat this by ensuring food & nutritional security for millions of people of poorer section biofortification is a sustainable solution (Bouis *et al*., 2011) [18]. It is a novel approach of increasing the micronutrient content or its bioavailability in edible parts via development of cultivars that efficiently utilize, uptake and translocate Fe and Zn. Being the 2nd most important staple crop in India, wheat is a better alternative for biofortification. Wheat varieties with improved nutrition quality and high grain yield can help to overcome the micronutrient malnutrition among resource poor people (Singh & Velu, 2017) [19]. For the effective selection of lines with higher grain Fe & Zn content along with yield, information on association of grain Fe & grain Zn content with other morpho-physiological traits that significantly affects grain yield is an added advantage. The effect of each trait on yield could be known through correlation studies, which determine the extent & nature of relationship among yield & yield attributing traits (Jaiswal *et al*., 2019).

The inter relationship among different components and their direct and indirect effect on grain yield can be quantified through path coefficient analysis. Hence, these together establish the extent of association between yield and other variables bringing out relative importance of their direct and indirect effects, thus giving an obvious understanding of their association with grain yield. Keeping these in view, the present investigation was carried out with the objective of studying the associations between grain Zinc and Iron content and yield attributing characters in wheat.

Material and Methods

In this investigation, two F_2 populations was generated from F_1 crosses of 4 diverse parents HPYT461, BHU31, HD2967 and HD2733 for micronutrient content which were selected & procured from department of Plant Breeding and Genetics, RPCAU, Pusa Samastipur, Bihar. The parents were crossed as following cross-I (HPYT 461 × HD 2733) and cross-II (BHU 31 × HD 2967) in which HPYT461 and BHU31 were used as female parent having high grain Zn & Fe content, while HD2967 and HD2733 were used as male parent having low grain Zn & Fe content but higher yield. The crosses were made during *Rabi* 2018 and the F_1 seeds were grown during *Rabi* 2019 to obtain F_2 seeds which were shown in Rabi 2020 for evaluation. The two F_2 populations obtained from these crosses were evaluated for 13 quantitative traits including yield and micronutrient traits during Rabi 2020 in compact family block design with 3 replications and data were recorded on individual plant basis of fifty plants per replication of each cross for all the traits. The estimation of micronutrient in wheat grain was done by X-Ray Fluorescence Spectrometry at HarvestPlus Division, ICRISAT, Hyderabad.

Biometrical Analysis

The analysis of association between the grain yield and micronutrient content was established through correlation and path analysis. Simple correlation coefficient was computed between pair of traits adopting the formula givenby Johnson *et al.*, 1955 [14]. Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as illustrated by Dewey and Lu., 1959 [13].

Results and Discussion

Correlation Analysis: Association between two or more traits in terms of degree and direction can be defined by correlation. In the present study genotypic and phenotypic correlation among different characters of F_2 population of two crosses were studied and their correlation matrix is presented in table 1. and 2.

The correlation coefficient among traits for cross-I (HPYT 461 × HD 2733) revealed that grain yield per plant exhibited significant and positive correlation with harvest index (0.280& 0.270) at both phenotypic and genotypic level (similar to Singh *et al.*, 2018) and positive and significant correlation with spike length (0.278) and with number of tillers/plant (0.305) only at genotypic level. While it showed highly significant and negative phenotypic and genotypic correlation with grain Zinc content (-0.766 & -0.798), grain Iron content (-0.895 & -0.974) and with days to 50% flowering (-0.421 & -0.470). Similar results were reported by Zhao *et al.*, 2009 [6] and Sharma *et al.*, 2018 [4] for grain Zinc content. A strongly significant and positive phenotypic and genotypic correlation was found between grain Zinc and Iron content (0.812, 0.904) as previously reported by Velu *et al.*, 2011 [1]. A positive and highly significant phenotypic and genotypic correlation was shown by chlorophyll content with days to 50 per cent flowering (0.465 & 0.488), plant height with days to 50 per cent flowering (0.388 & 0.400) and chlorophyll content (0.385 & 0.403), days to maturity with spike length (0.465 & 0.480), thousand grain weight with spike length (0.334 & 0.374) and number of tillers/plant (0.352 & 0.650), harvest index with number of tillers/plant (0.405 & 0.861) and thousand grain weight (0.416 & 0.427), grain Zinc content with thousand grain weight (0.410 & 0.448) and grain Iron content with days to 50 per cent flowering (0.391 & 0.437) while negative and highly significant correlation was showed by spike length with days to 50 per cent flowering (-0.677 & -0.707), number of tillers/plant with days to 50 per cent flowering (-0.353 & -0.706), thousand grain weight with chlorophyll content (-0.417 & -0.444) and harvest index with days to 50 per cent flowering (-0.384 & -0.394) and chlorophyll content (-0.556 & -0.585). Similar results were reported by Barnwal *et al.*, 2012 [3] and Ojha *et al.*, 2018 [7] for chlorophyll content and days to flowering while by Singh *et al.*, 2010 [9] and Singh *et al.*, 2021 [9] for harvest index and thousand grain weight and by Velu *et al.*, 2011 [1] for grain Zinc content and thousand grain weight.

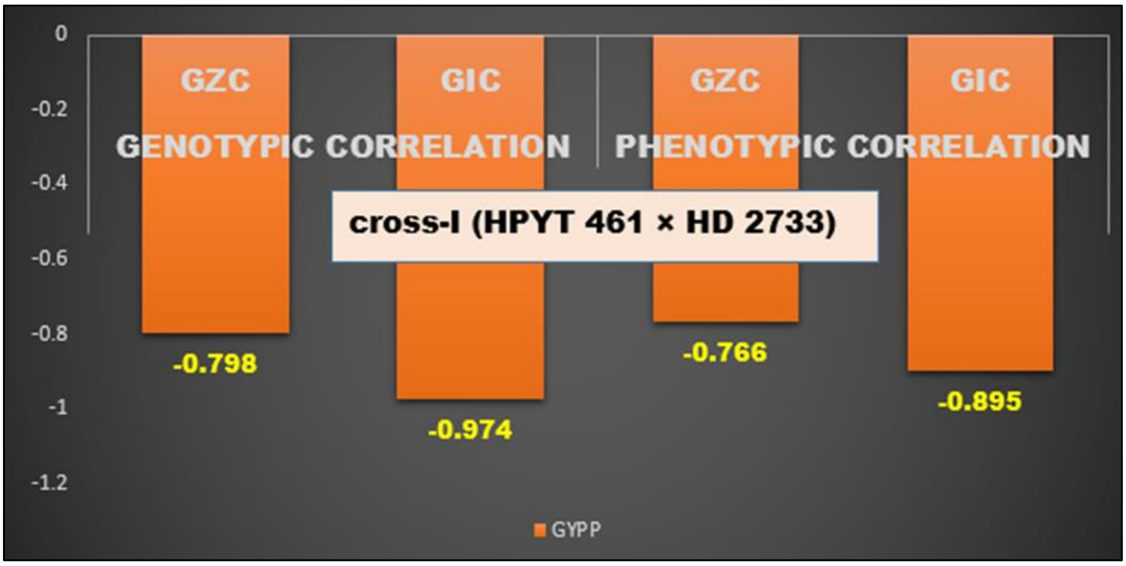

Chart 1: Genotypic and Phenotypic correlation of Grain Zinc and Iron content with grain yield per plant for cross-I (HPYT 461 × HD 2733)

Cross-II (BHU 31 × HD 2967) revealed that grain yield per plant exhibited highly significant and positive phenotypic and genotypic correlation with spike length (0.589 & 0.733) and harvest index (0.466 & 0.462; similar to Singh *et al.*, 2010) [9] and highly significant and positive genotypic correlation with days to maturity (0.352) while significant and negative genotypic correlation with number of tillers/plant (-0.330). Similar result was reported by Verma *et al*., 2019 [2] and Baranwal *et al*., 2012 [3]. Grain Zinc content showed negative and non-significant phenotypic and genotypic correlation with grain yield per plant (-0.035 & -0.090). Likewise grain Iron content also exhibited negative and non-significant phenotypic and genotypic correlation with grain yield per plant (-0.128 & -0.007). Similar results were reported by Sharma *et al.*, 2018 [4]. A significant and positive phenotypic and genotypic correlation was found between grain Zinc and Iron content (0.340 & 0.262). Similar results were also observed by Morgounov *et al*., 2007 [5] and Zhao *et al.*, 2009) [6]. A positive and significant correlation was observed between plant height and days to 50 per cent flowering (0.366 & 0.404), spike length and chlorophyll content (0.283 & 0.313) and among harvest index and spike length (0.460 & 0.474) and number of grains per spike (0.273 & 0.300) while negative and significant correlation was exhibited by plant height with chlorophyll content (-0.302 & -0.303) and harvest index with days to 50 per cent flowering (-0.327 & -0.454).

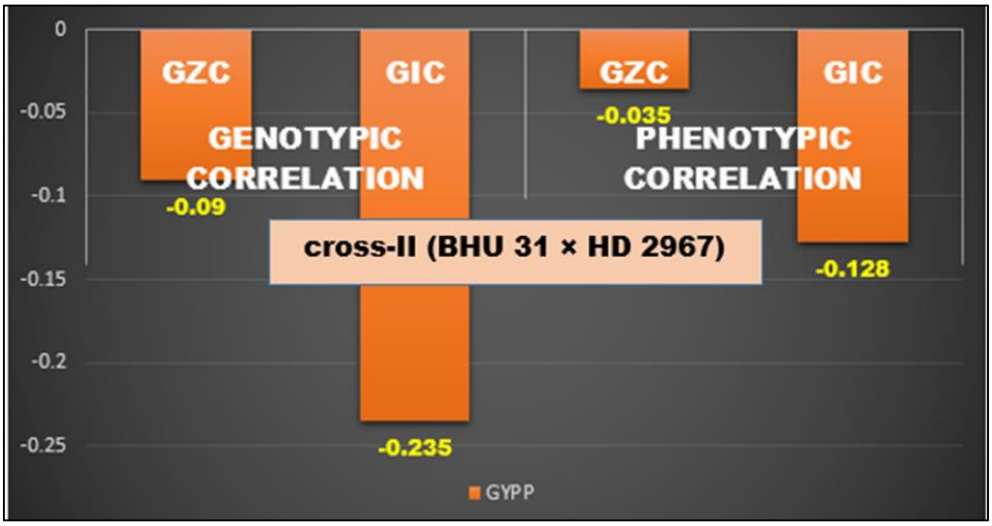

Chart 2: Genotypic and Phenotypic correlation of Grain Zinc and Iron content with grain yield per plant for cross-II (BHU 31 × HD 2967)

Path analysis

Phenotypic and genotypic path matrix among different characters of F_2 population from two crosses is presented in table 3 and 4.

Phenotypic Path Matrix

In present study the phenotypic path matrix for cross I (HPYT 461 × HD 2733) highest direct positive effect on grain yield was shown by plant height (0.148) followed by spike length (0.142), canopy temperature (0.131), days to maturity (0.105), harvest index (0.071), number of grains per spike (0.029), number of tillers/plant (0.023) and days to 50 per cent flowering (0.009) while the highest direct negative effect was shown by grain Iron content (-0.610) followed by grain Zinc content (-0.371), chlorophyll content (-0.159) and thousand grain weight (-0.059). The highest positive indirect effect was shown by harvest index via chlorophyll content (0.088) while lowest positive indirect effect was shown by number of grains per spike via days to 50 per cent flowering and grain Iron content via number of grains per spike (0.001). Further, the highest negative indirect effect on grain yield was shown by grain Zinc content via grain Iron content (-0.495), while the lowest negative indirect effect was shown by thousand grain weight via number of grains per spike and canopy temperature via number of grain per spike (-0.001). Singh *et al*., 2010 [9] reported similar observation for direct positive effect of harvest index on grain yield.

cross-II (BHU 31 × HD 2967) revealed that highest direct positive effect on grain yield was shown by number of grains per spikes (0.555) followed by harvest index (0.545), spike length (0.435), number of tillers/plant (0.177), days to maturity (0.147), days to 50 per cent flowering (0.139) and thousand grain weight (0.059) while the highest direct negative effect was shown by grain Zinc content (-0.381) followed by grain Iron content (-0.285), canopy temperature (-0.250), chlorophyll content (-0.227) and plant height (-0.082).The highest positive indirect effect was shown by spike length via harvest index (0.251) while the lowest positive indirect effect was shown by number of tillers/plant via thousand grain weight and canopy temperature (0.001). Further, the highest negative indirect effect on grain yield was shown by days to 50% flowering via harvest index (-0.178) while the lowest negative indirect effect was shown by canopy temperature via number of tillers/plant (-0.001). Similar results were reported by Singh *et al*., 2010 [9]; Sharma *et al.*, 2018 [4] and Singh *et al.*, 2021 [10] for direct positive effect of harvest ind ex on grain yield.

Genotypic Path Matrix

Present study of genotypic path matrix for cross I (HPYT 461 × HD 2733) highest direct positive effect on grain yield was shown by grain Iron content (0.368) followed by harvest index (0.315) canopy temperature (0.314), plant height (0.201), spike length (0.184), number of grains per spike (0.114), thousand grain weight (0.092) and days to maturity (0.005) while the highest direct negative effect was shown by grain Zinc content (-1.414) followed by days to 50 per cent flowering (-0.232), chlorophyll content (-0.183) and number of tillers/plant (-0.099). The highest positive indirect effect was shown by grain Zinc content via grain Iron content (0.333) while the lowest positive indirect effect via grain Zinc content and grain Iron content via days to maturity (0.001).

Further, the highest negative indirect effect on grain yield was shown by thousand grain weight via grain Zinc content (-0.634) while lowest negative indirect effect was shown by number of grains per spike via days to maturity (-0.001). Similar results were reported by Singh *et al.*, 2013 [8] for direct positive effect of harvest index and Yadav *et al.*, 2006 [11] for direct positive effect of number of grains per spike on grain yield and by Barnwal *et al.*, 2012 [3] for direct negative effect of chlorophyll content on grain yield.

cross-II (BHU 31 × HD 2967) revealed that highest direct positive effect on grain yield was shown by spike length (1.274) followed by plant height (0.436), number of grains per spike (0.028) and days to maturity (0.018) while the highest negative direct effect was shown by number of tillers/plant (-0.748) followed by days to 50 per cent flowering (-0.414), harvest index (-0.299), chlorophyll content (-0.218), grain Iron content (-0.133), grain Zinc content (-0.111), canopy temperature (-0.107) and thousand grain weight (-0.035). The highest positive indirect effect was shown by harvest index via spike length (0.604) while lowest positive indirect effect shown by canopy temperature via number of grains per spike (0.001), number of grains per spike via canopy temperature (0.001) and number of tillers/plant via grain Zinc content (0.001). Further highest negative indirect effect was shown by number of grains per spike via number of tillers/plant (-0.346). However, the lowest indirect effect was exhibited by number of tillers/plant via grain Iron content (-0.001). Similar results were reported by Ojha *et al.*, 2018 [7] for direct positive effect of number of grains per spike.

Table 1: Estimates of phenotypic and genotypic correlation coefficient among yield attributing traits and micronutrient content for cross- I (HPYT461× HD 2733)

Traits	DTF	CC	PH	SL	NT	DTM	GPS	TGW	HI	CT	GZC	GIC	GYPP
DTF	1.000	0.465**	0.388**	-0.677**	-0.353**	-0.295*	0.156	-0.289*	-0.384**	0.062	0.112	0.391**	-0.421**
CC	0.488**	1.000	0.385**	-0.298*	-0.258*	0.043	-0.280*	-0.417**	-0.556**	-0.121	-0.197	0.097	-0.167
PH	0.400**	0.403**	1.000	-0.295*	0.134	0.088	-0.21	0.049	-0.09	0.158	0.021	0.126	-0.018
SL	-0.707**	-0.311*	-0.311*	1.000	0.151	0.465**	-0.074	0.334**	0.179	-0.156	0.022	-0.13	0.234
NT	-0.706**	-0.528**	0.168	0.354**	1.000	0.101	-0.141	0.352**	0.405**	0.102	0.154	-0.01	0.08
DTM	-0.303*	0.029	0.09	0.480**	0.184	1.000	-0.097	0.099	0.053	-0.043	0.144	0.154	0.019
GPS	0.159	-0.292*	-0.218	-0.073	-0.252	-0.101	1.000	-0.025	-0.095	-0.038	0.083	0.043	0.047
TGW	-0.298*	-0.444**	0.045	0.374**	0.650**	0.103	-0.034	1.000	0.416**	0.352**	0.410**	0.108	0.065
HI	-0.394**	-0.585**	-0.089	0.181	0.861**	0.051	-0.102	0.427**	1.000	0.400**	0.156	-0.213	0.280*
CT	0.016	-0.167	0.17	-0.139	0.318*	-0.048	-0.063	0.402**	0.461**	1.000	0.414**	0.246	-0.147
GZC	0.142	-0.215	0.025	0.000	0.212	0.133	0.096	0.448**	0.19	0.575**	1.000	0.812**	-0.766**
GIC	0.437**	0.139	0.135	-0.193	-0.156	0.173	0.07	0.14	-0.204	0.316*	0.904**	1.000	-0.895**
GYPP	-0.470**	-0.175	-0.02	0.278*	0.305*	0.033	0.068	0.070	0.270	-0.204	-0.798**	-0.974**	1.000

*and **: Significance at 5% and 1% respectively.

Above diagonal values are phenotypic correlation coefficient and below diagonal values are genotypic correlation coefficient.

DTF: Days to 50% flowering; CC: Chlorophyll content; PH: Plant height; SL; Spike length; NT: Number of tillers/plant; DTM: Days to maturity; GPS: Number of grains per spike; TGW: Thousand grain weight; HI: Harvest index; CT: Canopy temperature; GZC: Grain Zinc content; GIC: grain Iron content; GYPP: Grain yield per plant

Table 2: Estimates of phenotypic and genotypic correlation coefficient among yield attributing traits and micronutrient content for cross- II (BHU 31 × HD2967).

Traits	DTF	CC	PH	SL	NT	DTM	GPS	TGW	HI	CT	GZC	GIC	GYPP
DTF	1.000	-0.125	0.366**	-0.012	-0.034	-0.038	-0.146	0.188	-0.327*	-0.014	-0.191	-0.231	0.045
CC	-0.156	1.000	-0.302*	0.283*	0.017	0.044	-0.238	-0.145	0.02	0.057	-0.102	-0.111	0.04
PH	0.404**	-0.303*	1.000	-0.172	-0.029	0.054	0.146	0.247	0.125	0.023	-0.268*	0.04	0.075
SL	-0.019	0.313*	-0.196	1.000	0.116	0.015	0.014	0.042	0.460**	-0.065	0.145	-0.079	0.589**
NT	-0.176	0.051	-0.025	0.315*	1.000	-0.041	0.229	0.011	0.148	-0.005	-0.038	-0.071	0.165
DTM	-0.188	0.129	0.107	-0.128	-0.226	1.000	0.078	0.189	0.026	-0.118	0.089	-0.019	0.098
GPS	-0.169	-0.239	0.145	0.010	0.463**	0.104	1.000	-0.089	0.273*	-0.047	-0.205	0.335**	0.084
TGW	0.187	-0.152	0.259*	0.043	0.079	0.418**	-0.099	1.000	-0.201	0.154	0.105	0.174	0.057
HI	-0.454**	0.035	0.144	0.474**	0.065	-0.314*	0.300*	-0.264*	1.000	0.24	0.141	0.096	0.466**
CT	-0.265*	0.076	0.055	-0.177	-0.055	-1.920**	-0.008	0.278*	0.296*	1.000	0.142	0.404**	-0.086
GZC	-0.219	-0.112	-0.282*	0.18	-0.008	0.092	-0.22	0.108	0.165	0.164	1.000	0.340**	-0.035
GIC	-0.266*	-0.122	0.043	-0.095	-0.006	-2.900*	0.369**	0.187	0.132	0.821**	0.262*	1.000	-0.128
GYPP	0.051	0.066	0.081	0.733**	-0.330*	0.352**	0.186	0.102	0.462**	-0.215	-0.09	-0.007	1.000

* and **: Significance at 5% and 1% respectively.

Above diagonal values are phenotypic correlation coefficient and below diagonal values are genotypic correlation coefficient.

DTF: Days to 50% flowering; CC: Chlorophyll content; PH: Plant height; SL; Spike length; NT: Number of tillers; DTM: Days to maturity;GPS: Number of grains per spike; TGW: Thousand grain weight; HI: Harvest index; CT: Canopy temperature; GZC: Grain Zinc content; GIC: grain Iron content; GYPP: Grain yield per plant

Table 3: Estimates of phenotypic and genotypic matrix of direct and indirect effectsof various traits under study on grain yield per plant for cross-I (HPYT 461 × HD 2733)

Traits		DTF	CC	PH	SL	NT	DTM	GPS	TGW	HI	CT	GZC	GIC	GYPP
DTF	P	0.009	-0.074	0.057	-0.096	-0.008	-0.031	0.005	0.017	-0.027	0.008	-0.041	-0.238	-0.421
	G	-0.232	-0.089	0.080	-0.130	0.070	-0.002	0.018	-0.027	-0.124	0.005	-0.201	0.161	-0.470
CC	P	0.004	-0.159	0.057	-0.042	-0.006	0.004	-0.008	0.025	-0.039	-0.016	0.073	-0.059	-0.167
	G	-0.113	-0.183	0.081	-0.057	0.052	0.000	-0.033	-0.041	-0.184	-0.052	0.304	0.051	-0.175
PH	P	0.003	-0.061	0.148	-0.042	0.003	0.009	-0.006	-0.003	-0.006	0.021	-0.008	-0.077	-0.018
	G	-0.093	-0.074	0.201	-0.057	-0.017	0.000	-0.025	0.004	-0.028	0.053	-0.036	0.049	-0.020
SL	P	-0.006	0.047	-0.044	0.142	0.004	0.049	-0.002	-0.020	0.013	-0.020	-0.008	0.079	0.234
	G	0.164	0.057	-0.063	0.184	-0.035	0.003	-0.008	0.034	0.057	-0.044	0.001	-0.071	0.278
NT	P	-0.003	0.041	0.020	0.021	0.023	0.011	-0.004	-0.021	0.029	0.013	-0.057	0.006	0.080
	G	0.163	0.097	0.034	0.065	-0.099	0.001	-0.029	0.060	0.271	0.100	-0.300	-0.057	0.305
DTM	P	-0.003	-0.007	0.013	0.066	0.002	0.105	-0.003	-0.006	0.004	-0.006	-0.054	-0.094	0.019
	G	0.070	-0.005	0.018	0.088	-0.018	0.005	-0.011	0.009	0.016	-0.015	-0.187	0.064	0.033
GPS	P	0.001	0.045	-0.031	-0.010	-0.003	-0.010	0.029	0.001	-0.007	-0.005	-0.031	-0.026	0.047
	G	-0.037	0.053	-0.044	-0.013	0.025	-0.001	0.114	-0.003	-0.032	-0.020	-0.136	0.026	0.068
TGW	P	-0.003	0.066	0.007	0.047	0.008	0.010	-0.001	-0.059	0.029	0.046	-0.152	-0.066	0.065
	G	0.069	0.081	0.009	0.069	-0.065	0.001	-0.004	0.092	0.134	0.126	-0.634	0.051	0.070
HI	P	-0.003	0.088	-0.013	0.025	0.010	0.006	-0.003	-0.024	0.071	0.052	-0.058	0.130	0.280
	G	0.091	0.107	-0.018	0.033	-0.086	0.000	-0.012	0.039	0.315	0.145	-0.269	-0.075	0.270
CT	P	0.001	0.019	0.023	-0.022	0.002	-0.005	-0.001	-0.021	0.028	0.131	-0.154	-0.150	-0.147
	G	-0.004	0.031	0.034	-0.026	-0.032	0.000	-0.007	0.037	0.145	0.314	-0.813	0.116	-0.204
GZC	P	0.001	0.031	0.003	0.003	0.004	0.015	0.002	-0.024	0.011	0.054	-0.371	-0.495	-0.766
	G	-0.033	0.039	0.005	0.000	-0.021	0.001	0.011	0.041	0.060	0.180	-1.414	+0.333	-0.798
GIC	P	0.003	-0.016	0.019	-0.018	0.000	0.016	0.001	-0.006	-0.015	0.032	-0.301	-0.610	-0.895
	G	-0.101	-0.025	0.027	-0.035	0.016	0.001	0.008	0.013	-0.064	0.099	-1.279	+0.368	-0.974

Residual effect (P) = 0.110 and Residual effect (G) =0.065

DTF: Days to 50% flowering; CC: Chlorophyll content; PH: Plant height; SL; Spike length; NT: Number of tillers/plant; DTM: Days to maturity; GPS: Number of grains per spike; TGW: Thousand grain weight; HI: Harvest index; CT: Canopy temperature; GZC: Grain Zinc content; GIC: grain Iron content; GYPP: Grain yield per plant.

Table 4: Estimates of phenotypic and genotypic matrix of direct and indirect effects of various traits under study on grain yield per plant for cross-II (BHU 31 × HD2967)

Traits		DTF	CC	PH	SL	NT	DTM	GPS	TGW	HI	CT	GZC	GIC	GYPP
DTF	P	0.139	0.028	-0.030	-0.005	-0.006	-0.006	0.081	0.011	-0.178	0.004	0.073	-0.066	0.045
	G	-0.414	0.034	0.176	-0.025	0.131	-0.003	0.005	-0.007	0.136	0.028	0.024	-0.035	0.051
CC	P	-0.017	-0.227	0.025	0.123	0.003	0.007	0.132	-0.009	0.011	-0.014	0.039	-0.032	0.040
	G	0.064	-0.218	-0.132	0.398	-0.038	0.002	0.007	0.005	-0.010	-0.008	0.012	-0.016	0.066
PH	P	0.051	0.069	-0.082	-0.075	-0.005	0.008	-0.081	0.015	0.068	-0.006	0.102	0.011	0.075
	G	-0.167	0.066	0.436	-0.250	0.019	0.002	-0.004	-0.009	-0.043	-0.006	0.031	0.006	0.081
SL	P	-0.002	-0.064	0.014	0.435	0.020	0.002	-0.008	0.002	0.251	0.016	-0.055	-0.023	0.589
	G	0.008	-0.068	-0.086	1.274	-0.236	-0.002	0.000	-0.002	-0.142	0.019	-0.020	-0.013	0.733
NT	P	-0.005	-0.004	0.002	0.050	0.177	-0.006	-0.127	0.001	0.081	0.001	0.014	-0.020	0.165
	G	0.073	-0.011	-0.011	0.401	-0.748	-0.004	-0.013	-0.003	-0.020	0.006	0.001	-0.001	-0.330
DTM	P	-0.005	-0.010	-0.004	0.006	-0.007	0.147	-0.043	0.011	0.014	0.030	-0.034	-0.006	0.098
	G	0.078	-0.028	0.047	-0.163	0.169	0.018	-0.003	-0.015	0.094	0.205	-0.010	-0.039	0.352
GPS	P	-0.020	-0.054	+0.012	-0.006	-0.040	-0.012	0.555	-0.005	-0.149	-0.012	-0.078	-0.095	0.084
	G	0.070	0.052	0.063	0.013	-0.346	0.002	0.028	-0.003	-0.090	0.001	-0.024	0.049	0.186
TGW	P	0.026	0.033	-0.020	0.018	0.002	0.028	0.049	0.059	-0.109	-0.039	-0.040	0.050	0.057
	G	-0.077	0.033	0.113	0.055	-0.059	0.008	0.003	-0.035	0.079	-0.030	-0.012	0.025	0.102
HI	P	-0.045	-0.005	-0.010	0.200	0.026	0.004	-0.151	-0.012	0.545	-0.060	-0.054	0.027	0.466
	G	0.188	-0.008	0.063	0.604	-0.049	-0.006	-0.008	0.009	-0.299	-0.032	-0.018	0.018	0.462
CT	P	-0.002	-0.013	-0.002	-0.028	-0.001	-0.017	0.026	0.009	0.131	-0.250	-0.054	0.115	-0.086
	G	0.110	-0.017	0.024	-0.225	0.041	-0.035	0.001	-0.010	-0.089	-0.107	-0.018	0.109	-0.215
GZC	P	-0.026	0.023	0.022	0.063	-0.007	0.013	0.113	0.006	0.077	-0.035	-0.381	0.097	-0.035
	G	0.091	0.024	-0.123	0.230	0.006	0.002	0.006	-0.004	-0.049	-0.018	-0.111	0.035	-0.090
GIC	P	-0.032	0.025	-0.003	-0.034	-0.013	-0.003	+0.186	0.010	0.052	+0.101	-0.130	-0.285	-0.128
	G	0.110	0.027	0.019	+0.121	0.004	-0.005	-0.010	-0.007	-0.039	-0.088	+0.029	-0.133	-0.007

Residual effect (P) = 0.373 and Residual effect (G) = 0.063

DTF: Days to 50% flowering; CC: Chlorophyll content; PH: Plant height; SL; Spike length; NT: Number of tillers/plant; DTM: Days to maturity; GPS: Number of grains per spike; TGW: Thousand grain weight; HI: Harvest index; CT: Canopy temperature; GZC: Grain Zinc content; GIC: grain Iron content; GYPP: Grain yield per plant.

Conclusions

In both the F_2 population grain yield per plant exhibited significant and positive phenotypic and genotypic correlation with harvest index and positive and significant genotypic correlation with spike length. Further, a negative correlation was observed between grain yield and grain Zinc and Iron content while the latter have positive correlation among themselves which showed that selection for higher micronutrient content may leads to decrease in grain yield. The genotypic and phenotypic path matrix in both the cross showed that number of grains per spikes, harvest index, spike length, number of tillers/plant, days to maturity and days to 50 per cent flowering have direct positive effect on yield while grain Zinc content, grain Iron content and chlorophyll content have direct negative effect on yield. These results inferred that harvest index and spike length could be used in indirect selection for yield.

Competing interests

Authors have declared that no competing interests exist.

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