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Research Article

Association and path analysis for agro-morphological traits among diverse wheat (*Triticum aestivum* L.) germplasm lines for Northern Hill Zone under rainfed conditions

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Abstract

The present investigation entitled 'Genetic diversity analysis for agro-morphological traits and disease resistance under rainfed conditions in wheat (*Triticum aestivum* L.)' was conducted at Rice and Wheat Research Centre, Malan and the Molecular Cytogenetics & Tissue Culture Laboratory of the Department of Genetics and Plant Breeding, CSK HPKV, Palampur. The objectives were to assess the diversity amongst wheat genotypes using various agro-morphological traits and molecular markers, and screening of genotypes for disease resistance at seedling (yellow rust and brown rust) and adult plant (yellow rust and powdery mildew) stage. The experimental material comprised of 36 wheat genotypes along with four checks *viz.*, HPW 368 (*Him Palam Gehun* 2), HS 562, Agra Local and LWH (Local Wheat Hango) were evaluated for different agro-morphological traits in α-Randomized Block Design with three replications during *rabi* 2021-22. Sufficient genetic variability was observed for all the traits *viz.*, days to 50% flowering, flag leaf area, peduncle length, plant height, tillers per plant, grains per spike, 1000-grain weight, biological yield per plant, grain yield per plant and harvest index except days to maturity, suggesting the scope of selection for these traits. Grain yield per plant showed significant and positive correlation with flag leaf area, tillers per plant, grains per spike, 1000-grain weight, biological yield per plant and harvest index. Also, biological yield per plant and harvest index were observed as the best selection indices for increasing grain yield owing to high direct and indirect effects of these traits in path analysis. This study suggests that biological yield per plant and harvest index can be used as selection criteria in breeding study to improve the high yielding wheat genotypes.

Key words : Genetic variation, Correlation, path coefficient, wheat, yield, yield components

1. Introduction

Wheat (*Triticum aestivum* L.) on account of its wide adaptation to various agro-climatic conditions has a prominent position among the grain crops in the world both in area and production. It is the leading grain crop of the temperate climate of the world. Globally wheat occupies 220.89 million hectares area with a production of 775.90 million tonnes and productivity 3.51 tonnes ha^{-1} (Anonymous, 2021a). At global level India has witnessed spectacular progress in wheat production and ranks as second largest wheat producing country next to China, contributing about one-tenth of the global wheat production. The wheat crop is grown over 31.36 million hectares area with total production of 107.90 million tonnes and productivity 3.44 tonnes ha^{-1} in India (Anonymous, 2021b). In Himachal Pradesh, wheat occupies an area of about 0.333 million hectare with total production of 0.57 million tonnes and productivity of 17.12 q ha^{-1} (Anonymous, 2021b). Yield of wheat is quantitative trait which is adversely affected by environmental factors. Therefore, only genotypic selection is not effective and selection should be based on performance of yield components and agro-morphological characters. Ali and shakor (2012) showed that correlation studies alone do not reveal such type of information and inadequate knowledge on inter-relationships between heritable traits may lead to negative results. On the other hand, path coefficient analysis measures the direct and indirect effect of different traits and allows separation of the correlation coefficient into direct and indirect effects (Dewey and Lu 1959). Hence, the information provided by correlations combined with path analysis for different characters along with the grain yield provides a better approach for planning efficient improvement programme. The present study was done to evaluate diverse wheat germplasm lines for various agro-morphological traits and to find out correlations among various traits to find out suitable selection criteria.

2. Material and Methods

The experimental material comprised of thirty six genotypes including high yielding cultivars recommended for North-Western Plain Zone, Northern Hill Zone and elite germplasm lines from national and international nurseries, few yellow rust resistant mutants of mega-cultivar HD 2967 along with other elite lines and cultivars from different sources (Table 1). In order to evaluate various agro-morphological traits of elite wheat germplasm lines by variability, correlation and path analysis the work was conducted during *rabi* 2020-2021 at the experimental area of Rice and Wheat Research Centre, Malan. Thirty six diverse lines of bread wheat (*Triticum aestivum* L.) were tested in -design with three replications. Observations recorded were based on five randomly selected plants from every genotype in three replications. Mean data of the 5 sample plants were used for data analyses. The data were subjected to analysis of variance (ANOVA) using IBM SPSS statistical software (version 20) (SPSS, 2020) as shown in Table 2. While, the analysis of various parameters of variability, correlation analysis and path analysis was done using online software packages. Path analysis was calculated following the procedure given by Wright (1921) and applied by Dewey and Lu (1959).

Table 1: Pedigree and source of the wheat genotypes used in study

Sr. No.	Genotypes	Pedigree	Source
1	*Bansi*	Indian Landrace	
2	DBW 187	NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU	ICAR-IIWBR, Karnal
3	EIGN 56 (2019-2020)	Elite Indian Germplasm Nursery	ICAR-IIWBR, Karnal
4	EIGN 24 (2019-2020)	Elite Indian Germplasm Nursery	ICAR-IIWBR, Karnal
5	HS 490	HS 364/HPW 114//HS 240//HS 346	ICAR-IARI, RS, Shimla
6	HS 507	KAUZ/MYNA/VUL//BUC/FLK/4/MILAN	ICAR-IARI, RS, Shimla
7	HPW 349	OASIS/SKUAZ114*BCN/3/PASTOR/4/KAUZ*2/YACO//KAUZ CMSS98Y01808T-040M-0100M-040Y-040M-030Y-1M-2Y-0M	RWRC, Malan
8	HPW 368	NAC/THAC//3*PVN/3/MIRLO/BUC/4/2/*PASTOR	RWRC, Malan
9	HPW 89	INTERMEDIORODI/HD 2248	RWRC, Malan
10	HD 2009	LR64A/NA/60	ICAR-IARI, New Delhi
11	IBWSN-232 (2019-2020)	International Bread Wheat Screening Nursery	CIMMYT, Mexico
12	IBWSN-284 (2019-2020)	International Bread Wheat Screening Nursery	CIMMYT, Mexico

13	NGSN 63 (2019-2020)	National Genetic Stock Nursery (2019-20)	ICAR-IIWBR, Karnal
14	NGSN 90 (2019-2020)	National Genetic Stock Nursery (2019-20)	ICAR-IIWBR, Karnal
15	PBW 677	PFAU/MILAN/5/CHEN/Ae.Sq.//BCN/3/VEE#7/BOW/4/PASTOR	PAU, Ludhiana
16	PBW 752	PBW621/4/PBW343//YR10/6*AVOCET/3/3*PBW343/5/PBW621	PAU, Ludhiana
17	PBW 723	PBW343+Lr57/Yr40+Lr37/Yr17	PAU, Ludhiana
18	Raj 4326	-	SKRAU, Durgapura
19	SDN 14	SDN 14 (2019-2020)	Short Duration Nursery (2019-2020)
20	SDN 17	SDN 17 (2019-2020)	Short Duration Nursery (2019-2020)
21	SDN 25	SDN 25 (2019-2020)	Short Duration Nursery (2019-2020)
22	SDN 37	SDN 37 (2019-2020)	Short Duration Nursery (2019-2020)
23	SDN 41	SDN 41 (2019-2020)	Short Duration Nursery (2019-2020)
24	Sonalika	MIDA-U/K1177A//2*TH/3/FN/4*TH/4/AN /5/YT54/NIOB//LR	RWRC, Malan
25	TAW 195	TAW142/BBW88	BARC, Mumbai
26	TAW 189	PBW677MUTANT/GW322//BAJ#1	BARC, Mumbai
27	TYRM 3	MUTANT OF HD 2967	BARC, Mumbai
28	TYRM 4	MUTANT OF HD 2967	BARC, Mumbai
29	VL 892	WH542/PBW226	RWRC, Malan
30	VL 3017	RWP2008-31/VL895	Almora
31	TYRM 2	MUTANT OF HD 2967	BARC, Mumbai
32	TYRM 1	MUTANT OF HD 2967	BARC, Mumbai
33	HD 2967	ALD/CUC//URES/HD2160M/HD2278	
34	HS 562	OASIS/SKAUZ//4*BCN/3/2*PASTOR	ICAR-IAR; RS, Shimla
35	LWH (Local Wheat Hango)	*Hango*	ICAR-IIWBR, RS, Flowerdale
36	Agra Local	Indian Landrace	BHU, Varanasi

3. Results and discussion

The analysis of variance showed that mean squares due to genotypes were found to be significant for all traits under study except days to 75% maturity, suggesting the prevalence of wide range of genetic variability and scope of selection for these traits in the present set of experimental lines (Table 2). The mean sum of squares due to blocks within replication was significant only for grains per spike, indicating significance of blocking within replication and better local control. The presence of substantial variability for almost every traits indicated the prevalence of adequate variability at the genetic level for selecting potential advance lines for wheat improvement. Singh *et al.* (2018) reported that the analysis of variance for grain yield and its contributing components namely days to 50% flowering, productive tillers, plant height, biological yield, harvest index, 1000-grain weight, grain yield and gluten content showed highly significant differences among the genotypes. Kumar *et al.* (2019) also reported that the mean squares due to genotypes were significant for the traits like days to 50% flowering, plant height, harvest index and grain yield per plant studied under field and controlled conditions, indicating that there was enough genetic variability among genotypes for these traits. High variability for different traits in wheat has also been reported by Ambati *et al.* (2020). Recently, Tanveer *et al.* (2022) also reported that mean sum of squares due to genotypes was significant for traits like plant height, flag leaf area, grains per spike, 1000-grain weight, biological yield per plant, grain yield per plant and harvest index among 21 released wheat varieties indicating sufficient genetic variability for these traits.

Table 2: Analysis of variance of 36 wheat genotypes for different traits

Sr. No.	**Traits**	**Mean sum of square**			
		Replication	**Blocks with in replication**	**Genotypes**	**Error**
	D.F.	**2**	**5**	**35**	**65**
1	Days to 50% flowering	75.69	34.37	128.76*	24.26
2	Days to 75% maturity	87.07*	7.84	33.98	23.11
3	Flag leaf area (cm^2)	25.15*	2.96	177.44*	3.48
4	Peduncle length (cm)	20.56*	0.55	48.08*	1.76
5	Plant height (cm)	7.55*	0.89	251.42*	1.86
6	Tillers per plant	0.06	0.50	1.21*	0.49
7	Grains per spike	5.30	83.17*	313.80*	26.30
8	1000-grain weight (g)	0.53	0.22	144.24*	0.81
9	Grain yield per plant (g)	1.67	1.18	17.23*	1.45
10	Biological yield per plant (g)	13.97	9.44	69.45*	8.34
11	Harvest index (%)	46.32	9.54	146.65*	30.61

*Significant at 5% level

In the present study, the estimates of phenotypic and genotypic correlation coefficients were computed for different characters which have been presented in Table 3. A perusal of Table 3 showed that phenotypic correlation coefficients were higher as compared to the corresponding genotypic correlation coefficients, indicating the inherent association among the traits.

At phenotypic level, grain yield per plant exhibited significant positive correlation with tillers per plant, grains per spike, 1000-grain weight, biological yield per plant and harvest index. These results corroborate the findings of earlier workers, Ali *et al.* (2008), Phougat *et al.* (2017), Sharma *et al.* (2018), Varsha *et al.* (2019) and Abdulhamed *et al.* (2021) in their correlation studies. Days to 50% flowering showed positive significant correlation with days to 75% maturity. On the contrary, studies conducted by Anwar *et al.* (2009) revealed that days to maturity and days to heading were non-significantly correlated to each other at phenotypic level. Days to 75% maturity expressed positive significant correlation with flag leaf area and grains per spike. Plant height showed positively significant correlation with peduncle length. Bogale *et al.* (2011) also reported a significant positive correlation between peduncle length and plant height. Tillers per plant showed positive significant correlation with grains per spike while grains per spike showed positive significant correlation with 1000-grain weight, biological yield and harvest index. Grains per spike had significant positive correlation with biological yield and days to maturity as reported by Anubhav *et al.* (2020). The correlation coefficient of 1000-grain weight with biological yield per plant and harvest index, was found to be positive and significant.

At genotypic level, grain yield per plant exhibited positive significant correlation with days to 75% maturity, flag leaf area, tillers per plant, grains per spike, 1000-grain weight, biological yield per plant and harvest index. These findings are in line with Parnaliya *et al.* (2015) and Hassani *et al.* (2022). Days to 75% maturity exhibited significant positive correlation with flag leaf area, tillers per plant, grains per spike, 1000-grain weight, biological yield per plant and harvest index. These correlations indicated that late maturing genotypes could get longer grain filling period. Flag leaf area exhibited significant positive correlation with grains per spike, 1000-grain weight and harvest index. Flag leaves are the main organs for photosynthesis, and contribute 45-58% of photosynthetic performance during the grain filling stage (Liu *et al.* 2018). These correlations indicated the importance of flag leaf area in selecting high yielding genotypes for rainfed conditions. The estimates of correlation coefficients for rest of the traits were generally similar to that observed at the phenotypic level. Similar findings have been reported by Pooja (2016). Bilgin *et al.* (2011) reported that correlation between grain yield

Table 3: Estimates of correlation coefficient at phenotypic level (P) and genotypic (G) among different traits of wheat

		Days to 75% maturity	Flag leaf area (cm^2)	Peduncle length (cm)	Plant height (cm)	Tillers per plant	Grains per spike	1000-grain weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield (g)
Days to 50% flowering	**P**	0.49*	-0.09	-0.31*	-0.03	-0.06	0.05	-0.02	-0.06	-0.20*	-0.18
	G	0.16	-0.12	-0.42*	-0.04	0.12	0.08	-0.01	0.05	-0.32*	-0.12
Days to 75% maturity	P		0.23*	-0.26*	-0.09	0.01	0.30*	0.10	0.11	0.07	0.08
	G		0.57*	-0.68*	-0.23*	0.47*	0.73*	0.24*	0.52*	0.36*	0.42*
Flag leaf area (cm^2)	P			-0.01	0.03	-0.02	0.22*	0.31*	0.11	0.24*	0.18
	G			-0.02	0.03	-0.07	0.25*	0.33*	0.15	0.32*	0.20*
Peduncle length (cm)	P				0.43*	0.02	-0.24*	0.20*	0.05	-0.08	0.04
	G				0.46*	0.02	-0.34*	0.21*	0.07	-0.15	0.03
Plant height (cm)	P					0.10	-0.16	-0.08	0.07	-0.06	0.03
	G					0.17	-0.19	-0.08	0.09	-0.07	0.03
Tillers per plant	P						0.20*	-0.13	0.44*	0.15	0.41*
	G						0.37*	-0.17	0.72*	0.49*	0.71*
Grains per spike	P							0.31*	0.34*	0.28*	0.33*
	G							0.35*	0.48*	0.38*	0.42*
1000-grain weight (g)	P								0.30*	0.33*	0.33*
	G								0.35*	0.43*	0.37*
Biological yield per plant (g)	P									0.39*	0.90*
	G									0.67*	0.96*
Harvest index (%)	P										0.68*
	G										0.85*

*Significant at 5% level

Table 3: Estimates of direct and indirect effects at phenotypic (P) and genotypic (G) level for different traits

Traits		Days to 50% flowering	Days to 75% maturity	Flag leaf area (cm^2)	Peduncle length (cm)	Plant height (cm)	Tillers per plant	Grains/ spike	1000-Grain weight (g)	Biological yield per plant (g)	Harvest index (%)	Correlation with yield
Days to 50% flowering	P	**-0.038**	0.000	-0.001	-0.010	0.001	-0.002	-0.002	0.000	-0.047	-0.078	-0.18
	G	**0.032**	0.002	0.002	-0.037	0.002	-0.006	-0.004	0.001	0.040	-0.150	-0.12
Days to 75% maturity	P	-0.019	**0.000**	0.003	-0.008	0.002	0.000	-0.009	-0.002	0.086	0.026	0.08
	G	0.005	**0.010**	-0.011	-0.061	0.010	-0.022	-0.033	-0.023	0.378	0.169	0.42*
Flag leaf area (cm^2)	P	0.003	0.000	**0.012**	0.000	-0.001	0.000	-0.007	-0.006	0.084	0.094	0.18
	G	-0.004	0.005	**-0.020**	-0.002	-0.002	0.003	-0.012	-0.032	0.113	0.149	0.20*
Peduncle length (cm)	P	0.012	0.000	0.000	**0.030**	-0.011	0.001	0.007	-0.004	0.036	-0.031	0.04
	G	-0.013	-0.007	0.000	**0.089**	-0.020	-0.001	0.015	-0.020	0.053	-0.071	0.03
Plant height (cm)	P	0.001	0.000	0.000	0.013	**-0.026**	0.003	0.005	0.002	0.055	-0.022	0.03
	G	-0.001	-0.002	-0.001	0.041	**-0.045**	-0.008	0.009	0.008	0.063	-0.032	0.03
Tillers per plant	P	0.002	0.001	0.000	0.001	-0.003	**0.027**	-0.006	0.003	0.328	0.059	0.41*
	G	0.004	0.004	0.001	0.002	-0.008	**-0.047**	-0.017	0.017	0.527	0.227	0.71*
Grains/spike	P	-0.002	0.000	0.003	-0.007	0.004	0.005	**-0.030**	-0.006	0.258	0.107	0.33*
	G	0.003	0.007	-0.005	-0.030	0.008	-0.018	**-0.045**	-0.034	0.355	0.175	0.42*
1000-Grain weight (g)	P	0.001	0.000	0.004	0.006	0.002	-0.003	-0.009	**-0.020**	0.223	0.127	0.33*
	G	0.000	0.002	-0.006	0.018	0.003	0.008	-0.016	**-0.098**	0.258	0.199	0.37*
Biological yield per plant (g)	P	0.002	0.000	0.001	0.002	-0.002	0.012	-0.010	-0.006	**0.750**	0.151	0.90*
	G	0.002	0.005	-0.003	0.006	-0.004	-0.034	-0.022	-0.034	**0.733**	0.311	0.96*
Harvest index (%)	P	0.008	0.000	0.003	-0.002	0.002	0.004	-0.008	-0.007	0.292	**0.388**	0.68*
	G	-0.010	0.004	-0.006	-0.014	0.003	-0.023	-0.017	-0.042	0.491	**0.465**	0.85*

Residual effects (R) = 0.0076 (G); 0.0587 (P)

The bold diagonal values indicates direct effects, off- diagonal values indicates indirect effects

G= Genotypic level and P= Phenotypic level and days to flowering were significant negative whereas, correlation of grain yield with days to maturity significant positive. The present findings are in concurrence with the findings of Parnaliya *et al.* (2015).

Based on correlation studies, it can be concluded that grain yield per plant is positively correlated with tillers per plant, grains per spike, 1000-grain weight, biological yield per plant and harvest index at both the phenotypic and genotypic levels and selection through these traits would be effective, while days to 75% maturity and flag leaf area exhibited significant positive correlation with grain yield at genetic level only. These results corroborate findings of earlier workers Parnaliya *et al.* (2015), Ramesh *et al.* (2016), Ayer *et al.* (2017), Sharma *et al.* (2018), Varsha *et al.* (2019), Anubhav *et al.* (2020) and Abdulhamed *et al.* (2021).

A perusal table 4 indicated that at genotypic level, biological yield, harvest index, peduncle length and days to 50% flowering had the highest positive direct effects, while flag leaf area had the highest negative direct effect on grain yield per plant (Table 4). The significant positive correlation of days to 75% maturity with grain yield at genotypic level mainly because of its indirect effect via biological yield and harvest index. Flag leaf area has negative direct effect of low magnitude but exhibited high positive indirect effect via harvest index and biological yield. Tillers per plant, grains per spike and 1000-grain weight also exhibited a high positive indirect effect on grain yield by a biological yield and harvest index leading to the positive correlation with a grain yield. The positive correlation of biological yield per plant with a grain yield per plant was mainly due to the high positive direst effect on grain yield per plant. The positive correlation of harvest index with the grain yield per plant was mainly due to the high positive direct effect as well as high positive indirect effect via biological yield per plant on grain yield per plant. Though 1000-grain weight had the lowest magnitude of direct effects but it exhibited high positive indirect effects mainly via biological yield per plant and harvest index, whereas low magnitude of negative indirect effects via flag leaf area was observed. A similar result of significant positive correlation of 1000-grain weight with grain yield was mainly due to positive indirect effects via biological yield and harvest was also reported by Anubhav *et al.* (2020). Present findings corroborate the findings of earlier workers Chander and Singh (2008), Dutamo *et al.* (2015), Parnaliya *et al.* (2015), Ayer *et al.* (2017), Varsha *et al.* (2019), Baye *et al.* (2020), Anubhav *et al.* (2020) and thus should be considered as important selection criteria for improving yield.

At phenotypic level, biological yield per plant followed by harvest index and tillers per plant had the highest positive direct effects leading to the significant positive correlation with the grain yield per plant. At phenotypic level also, most of the traits exhibits high positive indirect effect via biological yield per plant and harvest index (Table 4.5). These findings are similar to earlier research workers Kotal *et al.* (2010), Anubhav *et al.* (2020) and Verma *et al.* (2022). Conclusively, it could be seen that most of the traits have lower magnitude of direct effects and exhibit high indirect effect via biological yield per plant and harvest index. However the significant positive correlations of biological yield per plant and harvest index with grain yield per plant were primarily because of their high direct effects. Importance of harvest index as selection criterion has also been highlighted in studies by researchers namely Anubhav *et al.* (2020) and Hassani *et al.* (2022).

Conclusion

ANOVA revealed sufficient variability and significant differences among genotypes for all the traits except for days to 75% maturity suggesting prevalence of wide range of genetic variability and scope of selection for these traits. On the basis of correlation and path analysis biological yield per plant and harvest index were observed to be best selection indices for increasing grain yield owing to the high direct and indirect effects of these traits.

Grain yield of wheat is determined by many yield attributing characters.

These yield attributing characters have both positive and negative correlation with grain yield.

Conclusively, biological yield and harvest index emerged as important components of grain yield which should be given due importance during direct and indirect selection aimed at improvement of grain yield in wheat under northern hill zone conditions. However, these genotypes need to be further evaluated in multilocation trials over the years or can also be utilized in future hybridization programme.

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Author contributions

Conceptualization of research (PS & VR); Designing of the experiments (PS, VR & SU); Contribution of experimental materials (PS & VS); Execution of field/lab experiments and data collection (PS & VR); Analysis of data and interpretation (PS & VS); Preparation of the manuscript (PS, VR, VS and SU).

Conflict of interest: No

Declaration

The authors declare no conflict of interest.

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