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Assessment of genetic variability and character association for grain yield and its component traits in bread wheat (*Triticum aestivum* L.)

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Abstract
A study was conducted for estimating genetic variability and characters association for eleven yield components using 169 genotypes (13 parents, 78 F_1 and 78 F_2) of bread wheat through half-diallel mating design during rabi season 2012-13 and 2013-14. The genetic variability, heritability in broad sense, genetic advance, correlation coefficients and path analysis were carried out for the assessment of genotypes through eleven yield component traits namely; days to 50% flowering, days to maturity, plant height, spike length, number of effective tillers per plant, number of grains per spikelet, number of grains per spike, 1000-grain weight, biological yield per plant, harvest index and grain yield per plant. Analysis of variance showed significant differences (at1% level of significance) for all the traits under study in both the generations (F_1 and F_2). The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for plant height followed by number of effective tillers per plant, biological yield per plant, grain yield per plant, while high heritability coupled with high genetic advance were recorded for plant height and spike length in both F_1 and F_2 generations, respectively. Grain yield per plant was positively and significantly associated with number of effective tillers per plant, spike length, number of grains per spike, 1000-grain weight, biological yield per plant and harvest index while significantly but negatively associated with plant height. Path analysis revealed that the traits namely biological yield per plant, number of effective tillers per plant, number of grains per spike, plant height and harvest index exhibited positive direct effects on grain yield at both phenotypic and genotypic level in both generation (F_1 and F_2). These results, thereby suggests that yield improvement in breads wheats could be possible by emphasizing these traits while making selections in early generations.

Keywords: Correlation, Genetic variability, Heritability, Path analysis and Yield components

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is an important cereal crop having major share in food and nutritional security of the country. It stands second next to rice in production among cultivated crops and has been considered as "versatile cereal food". India`s share in world wheat area is about 12.5%, whereas it also contributes 12% in total world wheat production (Anonymous, 2016). In India, wheat crop is planted to an area of 30.23 million hectares and with production amounting to 93.50 million tons (Anonymous, 2017). Wheat is grown under diverse agro-climatic conditions leading to wide fluctuation in productivity from region to region. There are three major wheat producing regions, these are North-Western Plains Zone (NWPZ), North-Eastern Plains Zone (NEPZ) and Central Zone (CZ) where, the prevailing conditions are highly suitable for wheat cultivation. Since the growing period of the crop becomes restricted due to sudden increase in the temperature after winter; the sowing time has an important bearing on production potential of a genotype. Moreover, in intensive production system, farmers have to adjust the sowing time to suit different crops (Banerjee *et al.,* 2006). Yield increases may be effectively tackled on the basis of performance of yield components and other closely related traits (Singh *et al*., 2008). Manifestation of wheat yield fluctuates widely as a result of its interaction with the environment, because grain yield in wheat is a complexly inherited character and is the product of several contributing factors that affect it directly or indirectly (Hristov *et al.,* 2011). The traits for which variability present should be highly heritable as the progress through selection depend on heritability, selection intensity and genetic advance of the trait. An estimate of genetic advance along with heritability is helpful in assessing the reliability of character for selection. Yield is complexly inherited character and it is dependent on several contributing traits, generally inherited quantitatively (Yadav *et al.,* 2011). With respect to their magnitude and nature, various morphological characters differ in their inter-relationship with yield, though they show a continuous variation and are influenced by environment. The traits with high heritability exhibiting positive association with yield can be used for indirect selection for yield and will serve as an alternate mode of selection for yield improvement. When the indirect associations become complex, path coefficient analysis is the most effective mean to find out direct and indirect causes of association among the different variables. Path coefficient analysis can discriminate between the realistic (genetic effects) and inflated (environmental effects) correlations (Yadav *et al.* 2011). Hence, the knowledge of direct and indirect effects of different components on yield is of prime importance in selection of high yielding genotypes. Hence, in the context of yield improvement, when selecting desirable genotypes it is very important to know the nature and extent of variation present within a set of breeding material as well as the interrelationship between each yield component and grain yield and the exact contribution of each component to yield *via* direct and indirect effects. It is known that the improvement of the genetic architecture of yield must be based on a more intensive study of individual yield components. Among the mating designs, diallel mating is most effective for ascertaining the systematic genetic architecture of metric traits within short periods. Therefore the main objective here, was to study the extent of genetic variability, heritability, genetic advance, correlation coefficient and path analysis of yield components and their implications in the early generation selection of better genotypes for improving grain yield in wheat.

MATERIALS AND METHODS

The material for the present investigation was comprised of 13 strains/varieties of bread wheat selected on the basis of wide variability for various yield components. The salient features of these parental lines are presented in (Table 1). The experimental material consisted 13 diverse genotypes (NW 1014, NW 2036, PBW 502, PBW 343, K 8962, HI 1563, DBW 14, RAJ 3765, RAJ 4120, HP 1744, UP 2490, UP 2425 and CBW 38) of bread wheat were planted at Main Experiment Station of Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) during *rabi* 2012-2013 for attempting crosses following 13 × 13 half diallel system. During off season in the year of 2013, F_1 seed of 78 crosses was planted at IARI Regional Research Station, Wellington, Tamil Nadu for generation advancement. In the next crop season (rabi 2013-2014), the final set of experimental material comprising 13 parents along with their 78 F_1s and 78 F_2s were evaluated in a randomized block design having three replications. Each genotype was planted in a single row plot of 3 m length with a spacing of 23 cm and 10 cm between rows and between plants in a row, respectively. All the recommended agronomic practices (recommended dose of fertilizers, irrigation, roughing) were followed to raise a good crop.
The observations were recorded on five randomly selected plants in parents, 10 plants in F_1 generation and 20 plants in F_2 generation for days to 50 % flowering, days to maturity, plant height (cm), spike length (cm), number of effective tillers per plant, number of spikelets per spike, number of grains per spike, 1000- grain weight (g), biological yield per plant (g), harvest index (%) and grain yield per plant (g).
The analysis of variance (ANOVA) was carried out following Panse and Sukhatme, (1967). Heritability (in narrow sense) in F_1 and F_2 generation was calculated as proposed by Crumpacker and Allard, (1962). The genetic advance as percent of mean was estimated as proposed by Robinson *et al.,* (1949). Genotypic and phenotypic coefficient of variation was calculated by the formula given by Burton and De vane, (1953). The phenotypic correlation coefficients were calculated as suggested by Al-Jibouri *et al.,* (1958). In path analysis; direct, indirect as well as residual effects were calculated. All the analysis work was done in Microsoft Excel as per the procedure given by Singh and Chaudhary, (1985).

RESULTS AND DISCUSSION

Genetic variability: Analysis of variance (ANOVA) showed high significant differences (at1% level of significance) among the treatments, parents, hybrids and parents *vs.* hybrids for days to 50 % flowering, days to maturity, plant height, spike length, number of effective tillers per plant, number of spikelets per spike, number of grains per spike, 1000- grain weight, biological yield per plant, harvest index and grain yield per plant

Table 1. Details of genotypes used as base material for present study.

Genotype	Pedigree	Developed by
NW-1014	HAHN'S'	NDUA&T, Faizabad
NW-2036	BOW/CROW/BUC/PUN	NDUA&T, Faizabad
PBW-502	W-485/PBW-343/RAJ-482	PAU, Ludhiana
PBW-343	ND/1945/RAL/BB/3/YACO'S'/4/VEE#5'S'	PAU, Ludhiana
K-8962	K 7401 /HD 2160	CSAUAT, Kanpur
HI-1563	MACS2496*2/MC10	IARI, Regional Station, Indore
DBW-14	RAJ 3765/PBW 343	IIW and BR, Karnal
RAJ-3765	HD2402/VL631	RAU, Durgapura
RAJ-4120	PBW343/V1	RAU, Durgapura
HP-1744	Ciano/Paruta/Chilero/Garuda	IARI-PUSA, Bihar
UP-2490	Not available in record	GBPUA&T, Pantnagar
UP-2425	HD2320/UP2262	Pantnagar
CBW-38	CNDO,VSA/R-143/ENTE/MEXICALI	IIWBR, Karnal

indicating the presence of considerable amount of genetic variability in the present set of material and further study would be meaningful (Table 2). The general mean of F_1 and F_2 crosses (Table 3) were greater than their corresponding parents for (spike length, number of effective tillers per plant, number of spikelets per spike, number of grains per spike, 1000-grain weight, biological yield per plant, harvest index and grain yield per plant) while lower for days to 50% flowering, days to maturity and plant height. Phenotypic coefficient of variation for all the traits studied was higher than the genotypic coefficient of variation (Table 3) which indicated the influence of environment in the expression of these metric traits. The highest value of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were recorded for plant height, number of effective tillers per plant, number of grains per spike, biological yield per plant, harvest index and grain yield per plant in both $F_1$and F_2 generations. The present result are supported by the findings reported by Singh *et al.* (2013) for days to maturityand plant height; Meena *et al.* (2014) for grains number per spike; Kumar *et al.* (2016) for harvest index; Singh *et al.,* (2018) for grain yield and biological yield in wheat crop. Present results revealed that useful variability in progenies may be utilized while making selection of suitable genotypes on the basis of different selection parameters to improve grain yield in wheat.

Heritability and genetic advance: In the present study (Table 3), high heritability in narrow sense (more than 30 %) was observed for days to 50% flowering (49.60), days to maturity (30.80), plant height (48.82), spike length (32.80) and number of effective tillers per plant (42.06) in F_1 generation whereas for days to 50% flowering (38.63), plant height (47.30) and spike length (32.30) in F_2 generation. Similar findings were also reported by Singh *et al.* (2012) for days to maturity; Singh *et al.* (2013) and Meena *et al.* (2014) for plant height; Singh *et al.* (2014) for tillers per meter, 1000 grain weight and grain yield in wheat. Highest genetic advance (mare than 20 %) was recorded for plant height (26.04), spike length (20.08), number of effective tillers per plant (41.05), number of per spike (30.99), biological yield (56.08), harvest index (54.51) and grain yield (21.73) in F_1 generation whereas for plant height (26.62), spike length (20.86), effective tillers per plant (50.07), number of grains per spike (23.57), biological yield per plant (58.37), harvest index (54.11) and grain yield per plant (23.36) in F_2 generation, indicating that selection based on these traits would be effective for improvement of wheat crop. Similar findings were also reported by Singh *et al.* (2014) for tillers per meter, 1000 grain weight and grain yield; Singh *et al.,* 2018 for biological yield and harvest index in wheat.

Estimates of high heritability coupled with high genetic advance of a character are more effective for making selection due to the fact that expression of these traits is controlled by additive gene action. Highest heritability along with highest genetic advance was recorded for plant height and spike length in both F_1 and F_2 generations, revealing the presence of additive and additive x additive type of gene effects in the expression of above traits. Highest heritability along with highest genetic advance for plant height and spike length was also reported by Singh *et al.* (2018). Therefore, present results indicated that useful variability in progenies developed through hybridization can be properly utilized and selection of suitable genotypes on the basis of different genetic parameters can be done to get high yield in bread wheat.

Genotypic and phenotypic correlation coefficient: The improvement of yield components and the knowledge of their association with its main component are beneficial in formulating the breeding programme. Genotypic correlation coefficients were, in general, slightly higher than the corresponding phenotypic correlation coefficient for almost all the traits and a close relationship between genotypic and phenotypic correlations for most of the traits indicating low environmental effects on the degree of association between various yield components (Table 4a and 4b). The correlation coefficients were estimated between grain

Table 2. Analysis of variance (ANOVA) for a set of 13 x 13 half-diallel mating design involving parents, F_1 and F_2 generations of bread wheat.

Source of variation	DF	Generation	Days to 50% flowering	Days to maturity	Plant height	Spike length	No. of effective tillers / plant	No. of spikelets / spike	No. of grains / spike	1000-grain weight	Biological yield / plant	Harvest index	Grain yield / plant
Replication	2	F_1	1.53	0.04	3.93	0.04	0.04	0.11	2.03	1.00	0.35	3.85	0.30
		F_2	0.14	0.22	1.51	0.03	0.02	0.41	2.58	0.21	0.54	14.70	0.25
Treatments	90	F_1	26.78**	8.13**	206.96**	1.61**	2.14**	5.53**	88.74**	24.73**	169.04**	39.14**	23.52**
		F_2	23.15**	8.01**	213.11**	1.70**	3.18**	6.08**	58.46**	31.19**	168.53**	52.10**	23.29**
Parents	12	F_1	19.68**	4.80**	261.16**	2.86**	1.57**	4.81**	16.55**	2.41**	16.32**	11.79**	3.46**
		F_2	19.68**	4.80**	261.16**	2.86**	1.57**	4.81**	16.55**	2.41**	16.32**	11.79**	3.46**
Hybrids	77	F_1	27.95**	8.69**	199.07**	1.43**	2.20**	5.38**	99.99**	28.00**	136.19**	40.01**	21.37**
		F_2	23.75**	8.44**	205.74**	1.54**	3.38**	6.19**	62.26**	35.77**	152.33**	58.44**	21.46**
Parent Vs. Hybrids	1	F_1	21.81**	4.95**	163.43**	0.05	4.68**	25.66**	89.09**	41.05**	4531.35**	300.26**	429.74**
		F_2	18.70**	13.01**	203.75**	0.28**	6.83**	12.66**	269.17**	24.57**	3242.48**	47.56**	402.03**
Error	180	F_1	0.72	0.58	2.72	0.02	0.02	0.68	0.95	0.84	0.68	2.88	0.29
		F_2	0.66	0.52	2.31	0.02	0.01	0.59	1.88	0.38	0.93	4.67	0.41
Total	272	F_1	9.35	3.07	70.31	0.55	0.72	2.28	30.01	8.75	56.38	14.89	7.98
		F_2	8.10	2.99	72.05	0.57	1.06	2.40	20.60	10.57	56.39	20.44	7.98

Table 3. Genetic variability for 11 yield components in F_1 and F_2 generation of bread wheat.

Trait	Range			Mean			PCV %		GCV %		h^2ns (%)		GA in % of mean	
	Parents	F_1	F_2	Parents	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Days to 50% flowering	70-78	69-81	68-81	72.92	73.61	73.56	4.16	3.88	4.00	3.72	49.66	38.63	10.15	9.41
Days to maturity	119-123	118-125	117-124	121.31	120.97	120.77	1.45	1.43	1.31	1.30	30.80	26.97	3.12	3.14
Plant height	68-103	66-105	65-103	83.90	82.00	81.78	10.26	10.41	10.06	10.24	48.82	47.30	26.04	26.62
Spike length	8.20-11	8.03-12.00	8.06-12.30	9.39	9.35	9.31	7.93	8.16	7.76	8.03	32.80	32.30	20.08	20.86
No. of effective tiller/plant	4.33-6.80	4.03-7.30	4.13-10.16	4.99	5.31	5.37	16.08	19.23	15.08	19.09	42.06	23.10	41.05	50.07
No. of spikelets / spike	15-20	14-22	14-22	16.87	17.62	17.39	8.59	8.93	7.21	7.77	21.10	25.28	15.97	17.85
No. of grains / spike	41-47	32-57	37-58	43.95	45.34	46.38	12.12	9.81	11.92	9.36	07.83	13.12	30.99	23.57
1000-grain weight	39-42	33-46	33-47	39.83	40.78	40.56	7.27	8.04	6.92	7.90	03.17	00.33	17.37	20.48
Biological yield / plant	22-31	22-48	22-49	25.08	35.05	33.52	21.49	22.48	21.36	22.29	03.48	07.50	56.07	58.37
Harvest index	38-45	32-49	31-49	40.51	37.93	39.48	10.19	11.46	9.16	10.07	19.16	10.10	21.73	23.36
Grain yield / plant	8.43-11.60	8.43-18.30	8.16-18.00	10.15	13.22	13.12	21.42	21.59	21.03	21.03	08.93	11.76	54.51	54.11

Table 4a. Genotypic and phenotypic correlation coefficient among 11 yield components of bread wheat (*Triticum aestivum* L.) in F_1generations.

Trait	r	Days to 50 % flowering	Days to maturity	Plant height	Spike length	No. of effective tillers/plant	No. of spike-let's/ spike	No. of grains/ spike	1000 -grain weight	Biological yield/ plant	Harvest index	Grain yield/ plant
Days to 50 % flowering	G	-	0.24	-0.51	-0.18	0.49	-0.36	-0.11	0.078	0.18	-0.08	0.14
	P	-	0.21**	-0.47**	-0.16**	0.48**	-0.28**	-0.09	0.078	0.17**	-0.06	0.14*
Days to maturity	G		-	-0.12	0.04	0.02	0.16	-0.11	0.014	0.06	-0.09	0.02
	P		-	-0.10	0.03	0.02	0.13*	-0.09	0.01	0.06	-0.08	0.01
Plant height	G			-	0.42	-0.25	0.1554	-0.02	-0.11	-0.26	-0.02	-0.26
	P			-	0.40**	-0.23**	0.13*	-0.02	-0.09	-0.25**	-0.02	-0.25**
Spike length	G				-	0.14	0.15	0.05	0.08	-0.01	0.07	0.02
	P				-	0.14*	0.12*	0.0475	0.07	-0.01	0.06	0.02
No. of effective tillers/ plant	G					-	-0.17	0.09	0.16	0.26	0.11	0.33
	P					-	-0.14*	0.09	0.16*	0.26**	0.09	0.31**
No. of spikelets/ Spike	G						-	0.19	0.05	0.35	-0.37	0.21
	P						-	0.15*	0.05	0.29**	-0.29**	0.16**
No. of grains/ Spike	G							-	0.70	0.62	0.26	0.75
	P							-	0.67**	0.61**	0.23**	0.72**
1000-grain eight	G								-	0.60	0.18	0.69
	P								-	0.57**	0.16**	0.65**
Biological yield/ Plant	G									-	-0.26	0.91
	P									-	-0.25**	0.89**
Harvest index	G										-	0.20
	P										-	0.15**

*, **; Significant at 5% & 1% probability levels, G= Genotypic correlation coefficient, P= Phenotypic correlation coefficient

Table 4b. Genotypic and phenotypic correlation coefficient among 11 yields componentsof bread wheat (*Triticum aestivum* L.) in F_2generations.

Trait	r	Days to 50 % flowering	Days to maturity	Plant height	Spike length	No. of effective tillers/plant	No. of spike-let's/ spike	No. of grains/ spike	1000 -grain weight	Biological yield/ plant	Harvest index	Grain yield/ plant
Days to 50 % flowering	**G**	-	0.14	-0.48	-0.20	0.36	-0.36	-0.06	-0.06	-0.02	0.07	0.02
	P	-	0.12*	-0.45**	-0.19**	0.35**	-0.29**	-0.06	-0.05	-0.02	0.05	0.01
Days to maturity	**G**		-	-0.07	0.04	-0.08	0.07	-0.21	-0.11	-0.21	0.18	-0.14
	P		-	-0.07	0.03	-0.07	0.06	-0.17**	-0.10	-0.19**	0.14*	-0.12*
Plant height	**G**			-	0.43	-0.26	0.23	-0.09	-0.05	-0.17	-0.21	-0.27
	P			-	0.41**	-0.25**	0.19**	-0.08	-0.05	-0.17**	-0.18**	-0.26**
Spike length	**G**				-	0.12	0.26	0.05	0.12	0.02	-0.04	0.00
	P				-	0.11	0.22	0.04	0.11	0.02	-0.04	-0.00
No. of effective tillers/ plant	**G**					-	-0.19	0.25	0.20	0.22	0.08	0.28
	P					-	-0.16**	0.24**	0.19**	0.21**	0.07	0.27**
No. of spikelet's/ Spike	**G**						-	0.09	0.10	0.16	-0.11	0.11
	P						-	0.08	0.09	0.13*	-0.10	0.09
No. of grains/ Spike	**G**							-	0.66	0.75	0.09	0.83
	P							-	0.62**	0.70**	0.08	0.78**
1000-grain weight	**G**								-	0.59	0.06	0.66
	P								-	0.57**	0.06	0.63**
Biological yield/ plant	**G**									-	-0.34	0.88
	P									-	-0.32**	0.85**
Harvest index	**G**										-	0.21
	P										-	0.16**

*, **; Significant at 5% & 1% probability levels, G= Genotypic correlation coefficient, P= Phenotypic correlation coefficient

Table 5a. Direct and indirect effects of yield components on grain yield in F_1 generation of bread wheat (*Triticum aestivum* L.)

Trait	Path	Days to 50 % flowering	Days to maturity	Plant height	Spike length	No. of effective tillers/ plant	No. of spikelet's/ spike	No. of grains/ spike	1000 -grain weight	Biological yield/ plant	Harvest index	Grain yield/ plant
Days to 50 % flowering	G	-0.0086	-0.0021	0.0044	0.0015	-0.0043	0.0031	0.0009	-0.0007	-0.0015	0.0007	0.1437
	P	-0.0065	-0.0013	0.0031	0.0011	-0.0031	0.0018	0.0006	-0.0005	-0.0011	0.0004	0.1419
Days to maturity	G	0.0005	0.0019	-0.0002	0.0001	0.0000	0.0003	-0.0002	0.0000	0.0001	-0.0002	0.0187
	P	0.0002	0.0007	-0.0001	0.0000	0.0000	0.0001	-0.0001	0.0000	0.0000	-0.0001	0.0145
Plant height	G	-0.0091	-0.0021	0.0179	0.0075	-0.0044	0.0028	-0.0004	-0.0019	-0.0046	-0.0003	-0.2551
	P	-0.0072	-0.0016	0.0153	0.0061	-0.0036	0.0020	-0.0003	-0.0015	-0.0038	-0.0002	-0.2466
Spike length	G	0.0015	-0.0003	-0.0035	-0.0084	-0.0012	-0.0012	-0.0004	-0.0006	0.0001	-0.0006	0.0215
	P	0.0011	-0.0002	-0.0026	-0.0065	-0.0009	-0.0008	-0.0003	-0.0005	0.0001	-0.0004	0.0202
No. of effective tillers/ plant	G	0.0113	0.0004	-0.0056	0.0032	0.0227	-0.0039	0.0019	0.0035	0.0059	0.0025	0.3270
	P	0.0103	0.0003	-0.0050	0.0029	0.0215	-0.0031	0.0018	0.0033	0.0055	0.0020	0.3126
No. of spikelet's/ Spike	G	0.0018	-0.0008	-0.0008	-0.0008	0.0009	-0.0051	-0.0009	-0.0002	-0.0018	0.0019	0.2048
	P	0.0004	-0.0002	-0.0002	-0.0002	0.0002	-0.0015	-0.0002	-0.0001	-0.0004	0.0004	0.1577
No. of grains/ Spike	G	-0.0016	-0.0016	-0.0004	0.0007	0.0013	0.0028	0.0150	0.0107	0.0093	0.0039	0.7463
	P	-0.0012	-0.0014	-0.0003	0.0007	0.0012	0.0021	0.0138	0.0092	0.0084	0.0032	0.7207
1000-grain weight	G	-0.0017	-0.0003	0.0023	-0.0015	-0.0034	-0.0010	-0.0152	-0.0215	-0.0130	-0.0039	0.6855
	P	-0.0011	-0.0001	0.0014	-0.0010	-0.0022	-0.0007	-0.0095	-0.0143	-0.0082	-0.0023	0.6466
Biological yield/ plant	G	0.1841	0.0610	-0.2628	-0.0084	0.2689	0.3614	0.6381	0.6210	1.0266	-0.2703	0.9113
	P	0.1711	0.0561	-0.2513	-0.0091	0.2577	0.2872	0.6099	0.5773	1.0063	-0.2509	0.8948
Harvest index	G	-0.0344	-0.0416	-0.0064	0.0276	0.0464	-0.1542	0.1075	0.0751	-0.1099	0.4172	0.2009
	P	-0.0250	-0.0337	-0.0069	0.0263	0.0418	-0.1294	0.1051	0.0736	-0.1119	0.4488	0.1510

Residual Effect (Genotypic) = 0.0674, Residual Effect (Phenotypic) = 0.0835

Table 5b. Direct and indirect effect of yield components on grain yield in F_2 generation of bread wheat (*Triticum aestivum* L.)

Trait	Path	Days to 50 % flowering	Days to maturity	Plant height	Spike length	No. of effective tillers/plant	No. of spike-let's/spike	No. ofgrains/ spike	1000 -grain weight	Biological yield/ plant	Harvest index	Grain yield/ plant
Days to 50 % flowering	G	**0.0227**	0.0032	-0.0110	-0.0046	0.0083	-0.0081	-0.0014	-0.0014	-0.0005	0.0015	0.0236
	P	**0.0095**	0.0012	-0.0043	-0.0018	0.0033	-0.0028	-0.0006	-0.0005	-0.0002	0.0005	0.0139
Days to maturity	G	-0.0013	**-0.0093**	0.0006	-0.0004	0.0007	-0.0005	0.0019	0.0010	0.0020	-0.0016	-0.1395
	P	0.0000	**0.0004**	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	-0.0001	0.0001	-0.1244
Plant height	G	-0.0113	-0.0016	**0.0233**	0.0100	-0.0059	0.0053	-0.0020	-0.0012	-0.0039	-0.0048	-0.2719
	P	-0.0024	-0.0004	**0.0054**	0.0022	-0.0013	0.0011	-0.0004	-0.0003	-0.0009	-0.0010	-0.2635
Spike length	G	0.0021	-0.0004	-0.0045	**-0.0105**	-0.0012	-0.0027	-0.0005	-0.0012	-0.0002	0.0004	0.0019
	P	0.0021	-0.0003	-0.0046	**-0.0112**	-0.0013	-0.0025	-0.0005	-0.0013	-0.0002	0.0004	-0.0013
No. of effective tillers/ plant	G	0.0047	-0.0010	-0.0033	0.0015	**0.0129**	-0.0025	0.0032	0.0026	0.0028	0.0010	0.2822
	P	0.0069	-0.0015	-0.0049	0.0023	**0.0199**	-0.0033	0.0047	0.0039	0.0043	0.0013	0.2725
No. of spikelet's/ Spike	G	-0.0027	0.0004	0.0017	0.0019	-0.0015	**0.0074**	0.0007	0.0008	0.0012	-0.0008	0.1110
	P	-0.0038	0.0010	0.0026	0.0029	-0.0022	**0.0131**	0.0010	0.0011	0.0017	-0.0013	0.0868
No. of grains/ Spike	G	-0.0003	-0.0011	-0.0005	0.0003	0.0013	0.0005	**0.0054**	0.0036	0.0040	0.0004	0.8297
	P	-0.0020	-0.0059	-0.0026	0.0014	0.0081	0.0026	**0.0341**	0.0211	0.0239	0.0029	0.7778
1000-grain weight	G	-0.0009	-0.0016	-0.0008	0.0017	0.0030	0.0015	0.0098	**0.0149**	0.0087	0.0009	0.6573
	P	-0.0012	-0.0023	-0.0011	0.0026	0.0045	0.0020	0.0141	**0.0227**	0.0130	0.0013	0.6308
Biological yield/ plant	G	-0.0233	-0.2165	-0.1731	0.0196	0.2271	0.1653	0.7750	0.6065	**1.0333**	-0.3469	0.8783
	P	-0.0220	-0.1889	-0.1605	0.0187	0.2079	0.1290	0.6821	0.5550	**0.9704**	-0.3090	0.8487
Harvest index	G	0.0339	0.0884	-0.1044	-0.0175	0.0376	-0.0552	0.0376	0.0319	-0.1691	**0.5037**	0.2077
	P	0.0268	0.0722	-0.0934	-0.0184	0.0336	-0.0525	0.0434	0.0291	-0.1632	**0.5125**	0.1537

Residual Effect (Genotypic) = 0.0280, Residual Effect (Phenotypic) = 0.1549 yield and its contributing traits revealed that grain yield was positively and significantly associated with number of effective tillers per plant, number of grains per spikelet, number of grains per spike, 1000-grain weight, biological yield per plant and harvest index at both genotypic and phenotypic level in both F_1 and F_2 generations while it was significantly but negatively associated with plant height in F_1 generation and with plant height and days to maturity F_2 generation at both genotypic and phenotypic levels. The positive and significant association of number of productive tillers per plant and 1000 grain weight (Singh *et al.,* 2014); number of productive tillers per plant, 1000 grain weight, number of grains per spike, biological yield per plant, harvest index and number of spikelets per spike with grain yield at both genotypic and phenotypic level were also earlier reported (Kumar *et al.*, 2016) in wheat crop.

It has been observed that positive and significant association was found among number of grains per spike; biological yield per plant, spike length, number of effective tillers per plant; 1000-grain weight and biological yield per plant at both genotypic and phenotypic level in both F_1 and F_2 generations. Hence, selection for these traits would also help in improving the grain yield in this crop because these are the major components for yield.

Path coefficient analysis: The results of path coefficient indicated that biological yield per plant, harvest index, number of effective tillers per plant, number of grains per spike and plant height in F_1 generation while biological yield per plant, harvest index, number of effective tillers per plant, number of grains per spike, number of spikelet's per spike, plant height and 1000 grain weight in F_2 generation exhibited positive phenotypic and genotypic direct effects on grain yield per plant (Table 5a and 5b). The number of effective tillers per plant, number of grains per spike, number of spikelet's per spike, biological yield per plant and harvest index had higher phenotypic and genotypic direct effects on grain yield per plant, thus, the correlation coefficient between grain yield and these contributing traits is real one, revealing that indirect selection for these traits would be effective in improving grain yield. The findings are in accordance with the earlier reports where direct positive effects for number of grains per spike (Khan and Dar 2010); number of tillers per plant (Narwal *et al*. 1999); number of grains per spike and number of tillers per plant (Meena et al., 2014); biological yield per plant and harvest index (Kumar *et al.,* 2015); number of grains per spike and plant height (Kumar *et al.,* 2017) has been reported in wheat.

The data indicated that different component traits had their indirect effect on grain yield per plant. Indirect contribution towards grain yield was exhibited by biological yield per plant *via* number of spikelets per spike, number of effective tillers per plant, 1000-grain weight and number of grains per spike in both F_1 and F_2 generations. Path coefficient analysis revealed that biological yield per plant had higher direct and indirect positive contributions towards grain yield. Hence, indirect selection for this trait would be effective in improving the grain yield. Thus, the material studied is of diverse nature and information emanated would help in designing the selection methodology which can further be used in the breeding programme for improvement of grain yield.

Conclusion

In conclusion, the present study reveals that wide genetic variability exists in wheat genotypes created through hybridization programme by half-diallel mating design. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for plant height, number of effective tillers per plant, biological yield per plant, grain yield per plant. Plant height and spike length showed a high heritability with high genetic advance in both F_1 and F_2 generations used here, indicating a significant scope for improving grain yield through selection. The high significant and positive correlations of grain yield per plant (at <1% level of significance) with number of effective tillers per plant, number of grains per spikelet, number of grains per spike, 1000-grain weight, biological yield per plant and harvest index while significantly but negatively associated with plant height. The traits viz., biological yield per plant, number of effective tillers per plant, number of grains per spike, plant height and harvest index exhibited positive direct effects on grain yield per plant at both phenotypic and genotypic level in both generation (F_1 and F_2), will help in improving grain yield through early generation selection. It is evident that genotypes developed might serve as good source of material for further breeding programme.

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