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Genetic variability and character association studies in wheat (*Triticum aestivum* L.)

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Abstract
Wheat (*Triticum aestivum* L.) is an important cereal crop of cool climates, and plays a key role in the food and nutritional security of India. The present investigation was aimed to establish the inter-relationship and direct and indirect effect of various yield components of wheat. An evaluation of 72 accessions of wheat germplasm for yield as well as quality traits in an augmented design revealed highly significant differences among the accessions for test weight, biological yield per plant, plant height and days to 50% flowering in case of block whereas the variation due to check were found highly significant for most of the characters. The genotypes exhibited higher grain yield were 4th STEMRRSN 6110, 20th HRWSN 2081, 43IBWSN 1034, 4th STEMRRSN 6116 and 20th HRWSN 2049. Economic yield per plant were showed highly significant and positive association with biological yield per plant, effective tillers/plant, plant height and flag leaf area whereas it had been found to be significant and positive with grains per spike. Path analysis identified biological yield per plant followed by peduncle length and effective tillers per plant showed as major positive direct contributors towards expression of economic yield per plant. Whereas, days to maturity, vigour index and harvest index had negative direct effect on economic yield per plant.

Keywords: Genetic variability, heritability, genetic advance, correlation, path analysis, seed vigour index, wheat

Introduction
Wheat (*Triticum aestivum* L.) a self pollinated crop of the Gramineae family (Sub-family-Poaceae) and genus *Triticum* is the second most important staple food crop of the world. The centre of origin of wheat is considered to be the south – west Asia due to availability of maximum variability in the region, and also known as the Fertile Crescent (singh and Upadhyay, 2013) [21]. Its cultivation is favored by long cool, moist weather during its early vegetative phase and followed by dry and warm weather for crop maturity. From "begging bowl" status in mid sixties, India has emerged as second largest producer of the wheat in the world after China and has increased production from 6.46 million tons in 1952 to 95.40 million tons in 2013-14 (Anon., 2014). Wheat is consumed in a variety of ways such as bread, chapatti, flour, suji, porridge etc. Most of the agronomic characters in crop plants are quantitative in nature. Yield is one such character that results due to actions and interactions of various component characters. Direct selection for grain yield could be misleading, therefore, information on the genetic variability and correlation of a quantitative traits with grain yield are helpful for making effective selection.
Seed is a basic input in agriculture and it plays a vital role in boosting up the productivity and economy of the country. Seed vigour is an important quality parameter which needs to be assessed to supplement germination and viability test to gain insight into the performance of a seed in the field or in storage.
It is a well – established fact that the progress in improvement of a crop depends on the degree of variability in the desired characters in the germplasm collection. In the present study therefore, variability for the yield and related attribute along with quality were estimated in a collection of 72 accessions.

Materials and Methods
Seventy two germplasms of Wheat with three checks under reclaimed salt affected soil and irrigated condition, were evaluated in an Augmented Block Design at Main Experiment Station of A.N.D. University of Agriculture & Technology, Kumarganj, Ayodhya during the

Rabi season of 2011-12. The entire experimental field was divided into 8 blocks of equal size and each block had 12 plots. Out of 12 plots in a block 9 plots were used for accommodating the test genotypes which were not replicated while remaining 3 were allocated to checks i.e. HUW 234, HD 2824, NW 2036 which were replicated. Each plot will consist of two rows of 3 m length, following inter and intra row spacing of 25 cm and 5 cm, respectively. Recommended cultural practices were applied to raise a good crop. Observation on yield and yield contributing characters were recorded. In each plot, five competitive plants were randomly selected for recording observations for all the quantitative characters except days to maturity, which was recorded on the plot basis. The data were recorded for the fifteen characters: days to 50% flowering, days to maturity, plant height (cm) number of reproductive tillers per plant, flag leaf area (cm^2), spike length (cm), peduncle length (cm), grain per spike (g), 1000-grain weight (g), biological yield per plant (g), economic yield per plant (g), harvest index (%), seed germination (%) (ISTA, 1985), seedling length (cm) and seed vigour index (Abdul Baki and Anderson, 1973). Statistical Analyses were done according to the standard statistical procedure.

Results and Discussion

Estimation of variability is one of the most important factors in any crop for identification of lines, which can generate further variability so that artificial selection of desirable genotype could be made. The results of analysis of variance for augmented design of experiment involving 72 wheat germplasm in 8 blocks and 3 checks was done for each of fifteen characters. The mean square due to blocks, checks and error for all the 15 characters are presented in Table: 1. The variance due to blocks was found to be non-significant for most of the characters except 1000-grain weight, plant height, days to 50% flowering and biological yield/plant, which showed highly significant at 1% probability level and economic yield per plant exhibited significant at 5% probability level.

Table 1: Analysis of variance (ANOVA) of augmented design for 15 characters of Wheat genotype

S. No.	Characters	Source of Variation		
		Blocks	Checks	Error
		d. f. (7)	d. f. (2)	d. f. (14)
1.	Days to 50% flowering	5.28**	61.54**	9.71
2.	Flag leaf area (cm^2)	7.59	25.75	14.78
3.	Ear length (cm)	0.26	0.26	0.16
4.	Plant height (cm)	10.09**	131.61**	21.18
5.	Effective tillers per plant	0.85	2.31**	0.64
6.	Peduncle length (cm)	8.36	85.03**	10.86
7.	Days to maturity	4.61	23.04**	4.74
8.	Grains/spike	51.48	18.57	21.71
9.	1000- grain weight (g)	38.13**	12.74	5.45
10.	Biological yield (g)	26.26**	72.08**	12.40
11.	Economic yield (g)	6.26*	7.46*	2.98
12.	Harvest index (%)	13.50	13.26	10.43
13.	Germination (%)	2.37	180.87**	27.27
14.	Seedling length (cm)	1.16	7.27*	2.45
15.	Vigour index	9378.59	226194.45	23918.38

*Significant at 5% probability level, ** Significant at 1% probability level.

However, the variation due to check was found to be highly significant for germination, plant height, peduncle length, biological yield per plant, days to 50% flowering and effective tillers per plant whereas the variation was found to be significant for economic yield per plant and seedling length and remaining characters constitute non-significant group for this trait.

Table 2: Range, mean and least significant differences (LSD) for 15 characters of wheat genotypes

Characters	Range		Mean	Range of parameters @ 5%			
	Minimum	Maximum		LSD_1	LSD_2	LSD_3	LSD_4
Days to 50% flowering	74.37	89.37	80.77	3.34	9.45	10.91	8.18
Flag leaf area (cm^2)	15.67	48.17	30.21	4.12	11.66	13.46	10.09
Ear length (cm)	7.70	16.13	10.16	0.42	1.20	1.39	1.04
Plant height (cm)	44.60	101.06	86.44	4.93	13.96	16.11	12.08
Effective tillers per plant	1.54	5.84	3.70	0.85	2.42	2.79	2.09
Peduncle length (cm)	9.19	27.75	16.33	3.53	9.99	11.53	8.65
Days to maturity	107.95	122.95	117.13	2.33	6.60	7.62	5.71
Grains/spike	22.72	65.58	46.50	4.99	14.13	16.32	12.24
1000- grain weight (g)	35.02	52.02	42.52	2.50	7.08	8.17	6.13
Biological yield (g)	13.75	35.02	23.59	3.77	10.68	12.33	9.25
Economic yield (g)	3.44	13.92	8.76	1.86	5.23	6.04	4.53
Harvest index (%)	35.65	50.82	42.85	3.46	9.79	11.31	8.48
Germination (%)	64.45	78.79	92.57	5.59	15.83	18.28	13.71
Seedling length (cm)	10.74	21.83	14.86	1.67	4.74	5.48	4.11
Vigour index	1042.74	2017.14	1393	165.85	469.09	541.66	406.25

LSD_1= Least significant differences between two check means.
LSD_2= Least significant differences between adjusted mean of two genotypes in same block
LSD_3= Least significant differences between adjusted mean of two genotypes in different block.
LSD_4= Least significant differences between adjusted mean of genotype and check mean.

A wide range of variation in mean performance of genotype (Table 2) was observed for all the characters under study. The comparison of mean performance of 15 entries for 15 different traits using least significant differences revealed existence of very high level of variability among the exotic and indigenous lines evaluated in the present study. The genotype, 4th STEMRRSN 6116 (13.92g) produced higher grain yield per plant and was also present in top non-significant group for biological yield (32.85g), effective tillers/plant (4.74g) and flag leaf area (36.23g) besides showing average mean performance for remaining traits. The ten genotypes possessing higher economic yield/plant though statistically inferior to 4th STEMRRSN 6116, were 43 IBWSN 1034 (13.39g), 20th HRWSN 2081 (13.35g), 20th HRWSN

2049 (13.22g), 43 IBWSN 1092 (12.89g), 17th ESWYT 333 (12.35g), 17th SAWYT 330 (11.92g), 27th SAWSN 3121 (11.52g), 19th HLWSN 5039 (11.35g) and 20th HRWSN 2027 (11.29g). These genotypes showed high mean performance for several other characters also. The second-high yielder, namely 43 IBWSN 1034 (13.39g) was also present in top non-significant group for flag leaf area (37.17cm), days to maturity (114.95cm), grains/spike (57.45) and biological yield (32.15g). The third high yielder genotypes 20th HRWSN 2081 (13.35g) supposed to be most desirable genotype and utilized as donor because this genotype was present in top non-significant group of most of the important yield contributing traits such as grains/spike (65.58), 1000-grain weight (34.09), harvest index (34.09), germination per cent (97.45%), and vigour index (1572.05) with having highest mean performance for grains/spike (65.58). The genotype, having fourth rank for 20th HRWSN 2049 (13.22g) was also present in op non-significant group for biological yield (29.85g), seedling length (16.93cm) and vigour index (19.75cm). The genotype, 43 IBWSN 1092 (12.89g) ranked fifth for economic yield potential was also present in top non-significant group for flag leaf area (41.07cm) and peduncle length (19.75cm). The sixth highest yielding genotype 17th ESWYT 333 (12.35g) was present in top non-significant group for days to maturity (111.95). The genotype, 17th SAWYT 330 (11.92g) ranking seventh for economic yield per plant was observed non-significant group for days to maturity (114.62), seedling length (19.53) and vigour index (1705.14). The seven high yielding genotypes discussed above for having high mean performance for economic yield and some other characters may be recommended for use in crop improvement programme as donor or recurrent parents for developing superior genotypes.

The results of simple correlation coefficients were computed among 15 quantitative characters and given in Table 3. The economic yield per plant showed positive and highly significant correlation with biological yield per plant, effective tillers per plant, plant height and flag leaf area whereas, grains per spike showed positive and significant correlation with it. The grain yield was found significant and negative correlation with days to maturity. Thus, biological yield per plant, effective tillers per plant, plant height and flag leaf area emerged as closely correlated yield attributes. The strong positive association of grain yield with one or more of the above traits has also been observed by previous workers (Subhani, 2000 [25]. Ayccek and Yldrm 2006 [9]. Chaitali and Bini, 2007 [11]. Deepti Bisht, 2009 [13] Aydin *et al.* 2010 [10]. Singh *et al.* 2010 [23]. Zaeifizadeh *et al.* 2011; Soni *et al.* 2011 [11]. Singh *et al.* 2012) [22]. Vigour index showed highly significant and positive association with seedling length, germination and 1000-grain weight while ear length and grains per spike showed significant and positive association. Effective tillers per plant exhibited significant and negative association with vigour index. Seedling length showed highly significant and positive correlation with days to 50% flowering and grains per spike. Ear length had significant and positive correlation, whereas effective tillers/plant exhibited significant and negative association with seedling length. The germination percentage exhibited non-significant association with all the characters. Harvest index showed highly significant and positive correlation with days to 50% flowering and days to maturity while it also had significant and positive association of peduncle length. Biological yield/plant showed highly significant and positive correlation with flag leaf area, plant height, and effective tillers/plant and significant and positive association with ear length and grains/spike. 1000-grain weight showed highly significant and positive correlation with days to 50% flowering and days to maturity exhibited significant and positive correlation with it, while effective tillers/plant was significant and negatively correlated. Grains per spike was found highly significant and positively correlated with days to 50% flowering, flag leaf area and ear length. Days to maturity showed highly significant and positive correlation with days to 50% flowering, while effective tillers per plant showed significant and negative correlation. Peduncle length had highly significant and positive correlation with plant height and flag leaf area. Effective tillers/plant was significant and negatively correlated with days to 50% flowering. Plant height showed significant and positive correlation with flag leaf area. Ear length showed highly significant and positive correlation with days to 50% flowering and flag leaf area. The flag leaf area showed non-significant correlation with all the characters.

The above discussion revealed that all the highly significant estimates of correlation coefficient observed among the important yield components such as biological yield/plant, harvest index, days to maturity, plant height and tillers/plant, ear length and days to 50% flowering is significant, were positive in nature. Remaining estimates were, non-significant, and mostly positive in nature. Thus, selection practiced for improving these traits individually or simultaneously is likely to bring improvement in others due to correlated response. This suggests that selection would be quite efficient in improving yield and these five yield components in wheat, especially in context of the germplasm collections evaluated.

Table 3: Estimate of simple correlation coefficient between different characters of wheat genotype

Characters	Flag leaf area (cm²)	Ear length (cm)	Plant height (cm)	Effective tillers/ plant	Peduncle length (cm)	Days to maturity	Grains /spike	1000-grain weight (g)	Biological yield (g)	Harvest index (%)	Germination (%)	Seedling length (cm)	Vigour index	Economic yield (g)
Days to 50% flowering	0.081	0.415**	-0.022	-0.238*	0.327**	0.442**	0.364**	0.313**	0.210	0.341**	-0.098	0.329**	0.177	0.013
Flag leaf area (cm²)		0.310**	0.263*	0.139	0.573**	-0.100	0.340**	-0.151	0.401**	0.031	0.124	0.079	0.117	0.408**
Ear length (cm)			0.168	-0.086	0.192	0.151	0.454**	0.223	0.275*	0.173	0.145	0.292*	0.255*	0.171
Plant height (cm)				0.183	0.317**	-0.199	0.066	-0.037	0.349**	-0.039	-0.022	0.075	0.053	0.398**
Effective tillers/ plant					-0.074	-0.286*	-0.176	-0.237*	0.531**	-0.059	0.025	-0.232*	-0.239*	0.468**
Peduncle length (cm)						0.154	0.192	0.042	0.212	0.235*	0.029	0.216	0.215	0.214
Days to maturity							0.128	0.287*	0.009	0.451**	0.001	0.040	0.025	-0.272*
Grains/								0.013	0.272*	0.019	0.051	0.349**	0.241*	0.236*

spike														
1000 grain weight (g)									0.114	0.162	0.145	0.223	0.296**	-0.013
Biological yield (g)										0.038	0.109	0.067	0.069	0.737**
Harvest index (%)											-0.030	0.110	0.041	-0.192
Germination (%)												0.0167	0.338**	0.098
Seedling length (cm)													0.836**	0.020
Vigour index														0.011

* Significant at 5% probability level, ** Significant at 1% probability level.

The results of path-coefficient analysis done using simple correlation coefficients among 15 quantitative characters are given in Table 4. Biological yield per plant exerted very high positive direct effects on economic yield per plant, while peduncle length, seedling length, grains per spike were other characters having considerable positive direct contribution towards grain yield/plant. Thus, biological yield per plant followed by peduncle length emerged as most important direct contributors towards economic yield per plant. Asif *et al.* 2004 [8]. Khan *et al.* 2005; Chaitali and Bini, 2007 [11]. Yousaf Ali *et al.*2008; Saktipada *et al.* 2008; Singh *et al.* 2008; Deepti Bisht, 2009 [13]. Khokhar *et al.* 2010; Singh *et al.* 2010 [23]. Khan *et al.* 2010; Soni *et al.* 2011 [24]. Yady *et al.* 2011 [11]. Mollasadeghi *et al.* 2011; Singh *et al.* 2012 [22]. have also identified biological yield/plant as a character making substantial direct positive contribution towards manifestation of grain yield in wheat. Days to maturity followed by vigour index, harvest index, days to 50% flowering and ear length contributed negative direct effect on economic yield per plant.

Table 4: Table Direct and indirect effect of different characters on grain yield per plant in wheat genoty

Characters	Days to 50% flowering	Flag leaf area (cm²)	Ear length (cm)	Plant height (cm)	Effective tillers/ plant	Peduncle length (cm)	Days to maturity	Grains/ spike	1000-grain weight (g)	Biological yield (g)	Harvest Index (%)	Germination (%)	Seedling length (cm)	Vigour index	Correlation with economic yield (g)
Days to 50% flowering	-0.047	-0.003	-0.019	0.001	0.011	-0.015	-0.021	-0.017	-0.014	-0.010	-0.016	0.004	-0.015	-0.008	0.013
Flag leaf area (cm²)	0.002	0.033	0.010	0.008	0.004	0.019	-0.003	0.011	-0.005	0.013	0.001	0.004	0.002	0.004	0.408
Ear length (cm)	-0.005	-0.004	-0.014	-0.002	0.001	-0.002	-0.002	-0.006	-0.003	-0.003	-0.002	-0.002	-0.004	-0.003	0.171
Plant height (cm)	-0.001	0.020	0.012	0.075	0.013	0.024	-0.015	0.005	-0.002	0.026	-0.003	-0.001	0.005	0.004	0.398
Effective tillers/ plant	-0.0118	0.006	-0.004	0.009	0.049	-0.003	-0.014	-0.008	-0.011	0.026	-0.002	0.001	-0.011	-0.011	0.468
Peduncle length (cm)	0.0381	0.066	0.022	0.036	-0.008	0.116	0.018	0.022	0.004	0.024	0.027	0.003	0.025	0.025	0.2104
D00ays to maturity	-0.088	0.020	-0.030	0.040	0.057	-0.031	-0.200	-0.025	-0.057	-0.002	-0.090	-0.000	-0.008	-0.005	-0.272
Grains/ spike	0.031	0.029	0.039	0.005	-0.015	0.016	0.011	0.087	0.001	0.023	0.001	0.004	0.030	0.021	0.236
1000- grain weight (g)	0.014	-0.006	0.010	-0.001	-0.010	0.001	0.012	0.000	0.044	0.005	0.007	0.006	0.010	0.013	-0.113
Biological yield (g)	0.133	0.255	0.174	0.222	0.338	0.135	0.006	0.173	0.073	0.635	0.024	0.069	0.043	0.044	0.735
Harvest index (%)	-0.048	-0.004	-0.024	0.005	0.008	-0.033	-0.063	-0.002	-0.022	-0.005	-0.140	0.004	-0.015	-0.005	-0.192
Germination (%)	-0.005	0.007	0.008	-0.001	0.001	0.001	0.000	0.003	0.008	0.006	-0.001	0.059	0.001	0.020	0.098
Seedling length (cm)	0.032	0.007	0.028	0.007	-0.022	0.021	0.004	0.034	0.022	0.006	0.010	0.001	0.098	0.082	0.020
Vigour Index	-0.029	-0.019	-0.042	-0.008	0.040	-0.036	-0.004	-0.040	-0.049	-0.011	-0.007	-0.056	-0.140	-0.168	0.011

Bold figure indicate direct effect, Residual effect = 0.5792

The direct effects of remaining characters were found to be too low to be considered of any consequence. The plant height, effective tillers/plant, peduncle length, grains per spike, flag leaf area and 1000-grain weight exerted substantial positive indirect effect on economic yield per plant via biological yield per plant. Days to 50% flowering, ear length and days to maturity showed considerable negative indirect effect on economic yield per plant via biological yield per plant. Thus, above mentioned characters emerged as most important indirect yield contributing characters because they showed substantial positive indirect effects towards grain yield/plant via biological yield per plant, which also made high direct contribution to grain yield. The six characters mentioned above have also been found as important contributors towards economic yield in wheat by earlier workers (Esmail, 2001; Sachan and Singh, 2003; Zaeifizadeh *et al*, 2011). The remaining estimates of indirect effects in this analysis were very low indicating their negligible indirect contribution towards grain yield/plant. Peduncle length exerted substantial positive direct effects on grain yield/plant and this trait was also showed considerable positive indirect effects via biological yield/plant on economic yield. Thus, the characters like peduncle length need special attention at the time of formulation of selection strategy due to their positive direct and indirect effects.

The existence of negative as well as positive direct and indirect effects by same character on grain yield/plant via one or other character simultaneously, presents a complex situation where a compromise is needed to attain proper balance of different yield components in determining ideotype for high grain yield in wheat. In contrary to most of the previous reports in wheat, comparatively smaller proportion of direct and indirect effects of different characters attained high order values in the present study. Majority of the estimates of direct and indirect effects were too low to be considered of any consequence. This may be attributed to presence of very high genetic variability and diversity in the fairly large number of exotic and indigenous varieties/lines. The existence of different character combinations in diverse varieties/lines might have led to different types of character associations in different lines. Thus, presence of several contrasting types of character associations and inter-relationships might have resulted into cancellation of contrasting associations by each other ultimately leading to lowering of the net impact or effect. In the present study, path analysis identified biological yield per plant, peduncle length and plant height as important direct yield contributing characters. Plant height, effective tillers per plant, peduncle length, grains per spike, 1000-grain weight, flag leaf area, germination per cent and seedling length emerged as most important indirect yield components. The characters mentioned above, merit due to consideration at the time of devising selection strategy aimed at developing high yielding varieties in wheat.

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