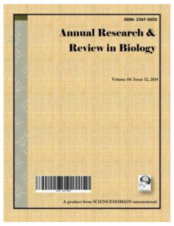

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Path Analysis and Genetic Parameters for Grain Yield in Bread Wheat (*Triticum aestivum* L.)

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

The experiment was conducted with 2 replications and 54 genotypes of wheat consisting 10 lines, 4 testers and their 40 crosses made in line X tester mating fashion in randomized block design during growing seasons 2014-2015. Spike length recorded the highest value of broad sense heritability while Canopy temperature index reported the highest value of genetic advance as a percent of mean and also reported highest phenotypic and genotypic coefficient of variation. Genotypic path analysis revealed that test weight and weight of grain/spike exhibited positive and strong association with grain yield and highest positive direct effects on grain yield. The selection for yield contributing test weight and weight of grain/spike must be given preference along with grain yield for speedy improvement grain yield.

Keywords: Genotypes; crosses; heritability; genetic advance; phenotypic.

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1. INTRODUCTION

Wheat is the principal food crop in most areas of the world and also occupies prominent position in Indian agriculture after rice. It is nutritionally important cereal essential for the food security, poverty alleviation and for livelihoods. It is widely cultivated as staple food crop among the cereals and is contributing about 30% to the food basket of the country. India is the second largest producer of wheat in the world with the production around 75 million tonnes during the last decade and it is a major contributor to the food security system in India, occupying nearly 30.37 million hectares, producing 90.78 million tonnes and productivity 29.89 q/ha and in Madhya Pradesh, grown in 5.56 million hectares with production of 13.37 million tonnes and productivity of 24.05 q/ha [1]. The substantial improvement in production is utmost necessary not only to meet ever-increasing food requirement for domestic consumption but also for export to earn foreign exchange. To feed the growing population, the country's wheat requirement by 2030 has been estimated at 100 million metric tonnes and to achieve this target, wheat production has to be increased at the rate of <1 per annum [2].

The extent of genetic variability has been considered as an important factor which is an essential pre-requisite for a successful hybridization aimed at producing high yielding progenies. The selection of parents becomes more difficult if the improvement is made for a polygenetically controlled complex character like grain yield. Since efficient selection of genetically superior individuals requires an adequate phenotypic variance in the base population and sufficient high heritability. Correlation studies along with path analysis provide a better understanding of the association of different characters with grain yield. Correlation is useful in disclosing the magnitude and direction of the relationship between various yield contributing traits and yield. While path coefficient (or) standardized partial regression coefficient that measures the direct effect of a predictor variable upon its response variable and the second component being the indirect effect(s) of a predictor variable [3]. Therefore the efforts were made to study the extent of variability, heritability and the possible amount of genetic gain expected to occur during the selection for yield improvement. At the same time, an attempt was made to analyze grain yield and its attributing traits of wheat by correlation and path coefficient analysis.

2. MATERIALS AND METHODS

Experiment was conducted with 2 replications and 54 genotypes consisting 10 lines *viz.*, 33rdESWYT150, 20thHRWYT213, 20thHRWYT235, 45thIBWSN1021, 14th FHBSN6418, 36thSAWSN3065, PBW658, KB2013-03, KB2013, VW921 and 4 testers *viz.*, GW273, GW366, RVW 4106, SUJATA and their 40 crosses made in L X T mating fashion in randomized block design at experimental Research Farm, College of Agriculture, Gwalior, (M.P.) during growing seasons 2014 and 2015. Observations averages were recorded on randomly selected 5 tagged plants for grain yield per plant and different yield contributing traits *viz.,* days to heading, days to maturity, plant height, tillers per plant, spike length, 1st internodes length, weight of spikes per plant, weight of grains per spike, grains per spike, test weight, canopy temperature index, biological yield and harvest index. The analysis was carried out by adopting the genetic parameters of variability, estimation of heritability and genetic advance were computed according to the method suggested by Johnson et al*.,* [4]. The character association was estimated from variance and covariance components as given [5,6] While the direct and indirect effects of component traits up on grain yield were measured by path analysis as described by Dewey & Lu [3].

3. RESULTS AND DISCUSSION

3.1 Phenotypic and Genotypic Coefficient of Variation (PCV and GCV)

Genetic variability is a prerequisite for any breeding program. It provides not only a sound basis for selection but also provides some valuable information regarding selection of diverse parent to be used in hybridization program. Wide range of variability for yield and yield components is also necessary to isolate significantly superior genotype for commercial cultivation to be used as a parent in hybridization for combination breeding to develop high yielding varieties / hybrids and to create useful genetic diversity for further selection. Phenotypic and genotypic coefficient of variation is used for the assessment of variability. Data presented in Table 1. Phenotypic and genotypic coefficient of variation (PCV and GCV) was recorded the highest value for canopy temperature index followed by harvest index and rest of the traits. Almost equal magnitude of GCV and PCV showed for days to heading, days to maturity, plant height, spike length, weight of spike/plant, grains/spike, test weight, grain yield/plant, canopy temperature index, biological yield and harvest index, indicating, that these characters were less influenced by the environment, whereas, tillers/plant and weight of grain/spike exhibited high value of PCV over its GCV value, indicating large amount of variation for this characters was due to environment only. Present finding are in harmony with Nukasani et al., [7], Singh and Upadhyay [8]

3.2 Heritability (Broad Sense) and Genetic Advance

Heritability provides information about the degree of inheritance of particular traits from parents to their offspring. Broad sense heritability is an important parameter for selection of parent. Selection based phenotypic values of the characters depend upon heritability and genetic advance, which are the result of breeding value and their inter-play with environment. Traits with high heritability and intense desirable correlation would give correlated response as a result of which selection process to be hastened. The estimates of broad-sense heritability% have been presented in Table 1. The percentage heritability in broad sense ranged from 73.88 to 99.11 and the maximum value of heritability was recorded for the character spike length followed by grain yield per plant, test weight, plant height, grains per spike, biological yield, harvest index, weight of spikes per plant, canopy temperature index, 1st inter-node length, days to maturity, days to heading, tillers per plant and weight of grains per spike.

In Table 1, the data of expected genetic advance over mean (%) ranged from 2.08 to 25.80. Higher genetic advance as percent of mean was expected for canopy temperature, harvest index. The moderate genetic advance as percent of mean was observed for spike length, grains per spike, test weight, grain yield per plant, tillers per plant, 1st inter-node length, weight of spike per plant, weight of grains per spike, biological yield, and plant height. Low genetic advance for days to maturity and days to heading.

Heritability are useful in predicting the transmission of characters from the parent to their offspring, while, genetic advance help in understanding the type of gene action involved in the expression of characters. In the present research work, high heritability was accompanied with high genetic advance for characters *viz.,* canopy temperature index, harvest index, spike length, grains per spike, test weight, grain yield per plant, tillers per plant, 1st inter-node length, weight of spike per plant, weight of grains per spike, biological yield and plant height indicated that most likely heritability is due to additive gene action and selection may be effective. High heritability with low genetic advance for days to heading and days to maturity, indicating presence of non additive gene action, high heritability was exploited due to favourable influence of environment rather than genotype and selection for such traits may not be rewarding. . Present finding are in confirmation with Zeeshan et al., [9], Nukasani et al., [7] and Singh et al., [10]

3.3 Correlation Analysis (PCV and GCV)

Correlation studies provide information about degree and direction of association of yield contributing characters. This information is useful to plant breeder in selection of elite genotype from genetic population. Phenotypic and genotypic correlation coefficient among grain yield per plant and its contributing characters are presented in Table 2 and Table 3. Phenotypic correlation is the observable correlation between two variables. It includes both genotypes and environmental effect and therefore, differs under different environmental condition so it is less stable than genotypic correlation. It revealed that grain yield showed significant and positive association with four yield contributing characters *viz*., test weight (0.9895); weight of spike/plant (0.8565); weight of grains/spike (0.7921) and harvest index (0.7667). Selection for these characters may lead instant yield improvement of wheat crop. Character viz., spike length (-0.4579), grain/spike (-0.3757) and days to maturity (-0.3077) exhibited negative and significant association with grain yield, indicating that the direct selection for these characters may not be helpful for improving the yield.

Genotypic correlation is an inherent association between two variables. It is more stable and is of paramount importance to the plant breeder to bring about genetic improvement in one character by selecting other character of pair that is genetically correlated. It revealed that grain yield was established positive and significant

Table 1. Range, mean, phenotypic coefficients of variation (PCV) and genotypic coefficient of variation (GCV), heritability (broad sense) and genetic advance for different characters in wheat

S. No	Characters	Range	Mean	GV	PV	GCV	PCV	Broad sense heritability (%)	Genetic advance	Genetic advance as % of mean
1	Days to heading	83.50 - 90	86.35	1.66	2.06	1.49	1.66	80.64	2.39	2.76
2	Days to maturity	134.50 - 141	136.97	2.32	2.82	1.11	1.23	82.55	2.85	2.08
3	Plant height (cm)	88.70 - 110.10	104.45	27.62	28.28	5.03	5.09	97.68	10.70	10.25
4	Tillers / Plant	6 - 8.40	7.12	0.24	0.33	6.95	8.06	74.34	0.88	12.35
5	1^{st} inter-node length (cm)	2.54 - 3.37	2.92	0.04	0.04	6.44	7.00	84.56	0.36	12.19
6	Spike length (cm)	8.35 - 12.07	10.25	0.90	0.91	9.26	9.30	99.11	1.95	18.99
7	Wt. of Spike/Plant (g)	20.09 - 24.58	22.06	1.84	2.01	6.15	6.42	91.61	2.67	12.12
8	Grains weight/Spike (g)	1.74 - 2.28	2.00	0.02	0.02	6.40	7.45	73.88	0.23	11.33
9	Grains/Spike	53.60 - 72.70	63.10	28.24	29.30	8.42	8.58	96.39	10.75	17.03
10	Test weight (g)	32.37 - 45.05	40.26	9.24	9.42	7.55	7.62	98.07	6.20	15.40
11	Grains yield/ Plant (g)	12.97 - 18.06	16.06	1.45	1.47	7.51	7.56	98.58	2.47	15.36
12	Canopy temperature index	0.25 - 0.41	0.27	0.00	0.00	13.21	13.93	89.91	0.07	25.80
13	Biological yield (g)	32.70 - 42.66	38.80	4.59	4.91	5.52	5.71	93.45	4.27	11.00
14	Harvest index (%)	34.13 - 54.75	42.52	19.42	21.00	10.37	10.78	92.52	8.73	20.54

Table 2. Phenotypic correlation coefficient among 14 traits of wheat

Traits	DH	DM	PH	TP	FIN	SL	GS	WGS	TW	BY	HI	CTI	WSP	GYP
DH	1.0000	0.0312	0.1456	-0.1438	-0.0872	0.0699	-0.1980	-0.0629	-0.0531	-0.1089	0.0472	0.2467	-0.0841	-0.0730
DM		1.0000	-0.5237*	0.0195	0.1435	0.0736	0.0018	-0.3009*	-0.2849*	0.1485	-0.3355*	-0.1228	-0.2619	-0.3077*
PH			1.0000	-0.0313	0.2442	-0.2208	-0.3010*	0.0627	0.0561	-0.1444	0.1241	0.1912	0.0778	0.0688
TP				1.0000	0.0143	-0.0464	-0.0049	0.1409	0.2142	-0.0808	0.2395	0.3027*	0.2127	0.2294
FIN					1.0000	-0.2499	-0.1686	0.0601	-0.0602	-0.0525	-0.0378	-0.1150	0.0072	-0.0596
SL						1.0000	0.8640**	-0.3163*	-0.4618**	-0.1928	-0.1766	0.0973	-0.3865**	-0.4579**
GS							1.0000	-0.2379	-0.3849**	-0.2051	-0.1135	-0.0316	-0.2857*	-0.3757**
WGS								1.0000	0.8094**	-0.2539	0.7232**	0.2768*	0.7115**	0.7921**
TW									1.0000	-0.1329	0.7795**	0.2394	0.8531**	0.9895**
BY										1.0000	-0.6739**	-0.6393**	-0.1613	-0.1087
HI											1.0000	0.5617**	0.6948**	0.7667**
CTI												1.0000	0.0013	0.2075
WSP													1.0000	0.8565**

**, ** significant at 5 and 1 per cent level, respectively, DH: Days to heading, DM: Days to maturity, PH: Plant height, TP: Tillers/plant, FIN: 1^{st} inter-node length, SL: Spike length, GS: Grains/spike, WGS: Weight of grains/spike, TW: Test weight, BY: biological yield, HI: harvest index, CTI: canopy temperature index, WSP: weight of spike/plant, GYP: grain yield/plant*

Table 3. Genotypic correlation coefficient among 14 traits of wheat

Traits	DH	DM	PH	TP	FIN	SL	GS	WGS	TW	BY	HI	CTI	WSP	GYP
DH	1.000	0.0535	0.1661	-0.1926	-0.1375	0.0643	-0.2361	-0.0580	-0.0665	-0.0997	0.0535	0.3077*	-0.0884	-0.0785
DM		1.0000	-0.5804**	0.0390	0.1828	0.0796	0.0291	-0.3690**	-0.3174*	0.1654	-0.3511*	-0.1659	-0.2911	-0.3385*
PH			1.0000	-0.0490	0.2719	-0.2222	-0.3120*	0.0673	0.0590	-0.1529	0.1346	0.1968	0.0848	0.0708
TP				1.0000	0.0188	-0.0641	0.0024	0.1613	0.2512	-0.1028	0.2598	0.3954**	0.2104	0.2663
FIN					1.0000	-0.2735*	-0.1826	0.0791	-0.0664	-0.0354	-0.0584	-0.1132	0.0046	-0.0661
SL						1.0000	0.8840**	-0.3696**	-0.4684**	-0.2003	-0.1844	0.1030	-0.4056**	-0.4632**
GS							1.0000	-0.2704	-0.3894**	-0.2213	-0.1149	-0.0443	-0.3098*	-0.3855**
WGS								1.0000	0.9198**	-0.2872*	0.8367**	0.3177*	0.8730**	0.9217**
TW									1.0000	-0.1411	0.8076**	0.2622	0.8941**	0.9992**
BY										1.0000	-0.6876**	-0.6844**	-0.1846	-0.1281
HI											1.0000	0.6279**	0.7513**	0.7966**
CTI												1.0000	0.1685	0.2320
WSP													1.0000	0.8985**

**, ** significant at 5 and 1 per cent level, respectively, DH: Days to heading, DM: Days to maturity, PH: Plant height, TP: Tillers/plant, FIN: 1st inter-node length, SL: Spike length, GS: Grains/spike, WGS: Weight of grains/spike, TW: Test weight, BY: biological yield, HI: harvest index, CTI: canopy temperature index, WSP: weight of spike/plant, GYP: grain yield/plant*

Table 4. Phenotypic path analysis: Direct (diagonal) and indirect effect of 14 traits on grains yield

Traits	DH	DM	PH	TP	FIN	SL	GS	WGS	TW	BY	HI	CTI	WSP	GYP
DH	-0.0527	-0.0022	-0.0145	0.0196	-0.0040	-0.0060	-0.0135	0.0063	-0.0072	-0.0390	0.0015	0.1217	-0.0828	-0.0730
DM	-0.0016	-0.0715	0.0521	-0.0027	0.0066	-0.0063	0.0001	0.0299	-0.0388	0.0532	-0.0103	-0.0606	-0.2578	-0.3077
PH	-0.0077	0.0375	-0.0995	0.0043	0.0112	0.0191	-0.0205	-0.0062	0.0076	-0.0517	0.0038	0.0943	0.0766	0.0688
TP	0.0076	-0.0014	0.0031	-0.1365	0.0007	0.0040	-0.0003	-0.0140	0.0291	-0.0290	0.0074	0.1493	0.2093	0.2294
FIN	0.0046	-0.0103	-0.0243	-0.0020	0.0460	0.0216	-0.0115	-0.0060	-0.0082	-0.0188	-0.0012	-0.0567	0.0070	-0.0596
SL	-0.0037	-0.0053	0.0220	0.0063	-0.0115	-0.0863	0.0589	0.0314	-0.0628	-0.0691	-0.0054	0.0480	-0.3804	-0.4579
GS	0.0104	-0.0001	0.0299	0.0007	-0.0078	-0.0746	0.0682	0.0236	-0.0524	-0.0735	-0.0035	-0.0156	-0.2812	-0.3757
WGS	0.0033	0.0215	-0.0062	-0.0192	0.0028	0.0273	-0.0162	-0.0994	0.1101	-0.0910	0.0223	0.1366	0.7002	0.7921
TW	0.0033	0.0204	-0.0056	-0.0292	-0.0028	0.0399	-0.0262	-0.0804	0.1360	-0.0476	0.0240	0.1181	0.8397	0.9895
BY	0.0057	-0.0106	0.0144	0.0110	-0.0024	0.0166	-0.0140	0.0252	-0.0181	0.3583	-0.0208	-0.3154	-0.1587	-0.1087
HI	-0.0025	0.0240	-0.0123	-0.0327	-0.0017	0.0152	-0.0077	-0.0719	0.1060	-0.2414	0.0308	0.2771	0.6838	0.7667
CTI	-0.0130	0.0088	-0.0190	-0.0413	-0.0053	-0.0084	-0.0022	-0.0275	0.0326	-0.2290	0.0173	0.4933	0.0013	0.2075
WSP	0.0044	0.0187	-0.0077	-0.0290	0.0003	0.0334	-0.0195	-0.0707	-0.0219	-0.0578	0.0214	0.0006	0.9842	0.8565

DH: Days to heading, DM: Days to maturity, PH: Plant height, TP: Tillers/plant, FIN: 1st inter-node length, SL: Spike length, GS: Grains/spike, WGS: Weight of grains/spike, TW: Test weight, BY: biological yield, HI: harvest index, CTI: canopy temperature index, WSP: weight of spike/plant, GYP: grain yield/plant

Table 5. Genotypic path analysis: Direct (diagonal) and indirect effect of 14 traits on grains yield

Traits	DH	DM	PH	TP	FIN	SL	GS	WGS	TW	BY	HI	CTI	WSP	GYP
DH	0.0065	-0.0012	0.0028	-0.0152	0.0032	0.0069	0.0245	-0.0063	-0.0688	0.0121	-0.0068	-0.0394	0.0033	-0.0785
DM	0.0003	-0.0224	-0.0099	0.0031	-0.0042	0.0085	-0.0030	-0.0399	-0.3280	-0.0200	0.0448	0.0213	0.0109	-0.3385
PH	0.0011	0.0130	0.0171	-0.0039	-0.0063	-0.0237	0.0323	0.0073	0.0609	0.0185	-0.0172	-0.0252	-0.0032	0.0708
TP	-0.0013	-0.0009	-0.0008	0.0791	-0.0004	-0.0068	-0.0002	0.0174	0.2596	0.0124	-0.0332	-0.0507	-0.0079	0.2663
FIN	-0.0009	-0.0041	0.0046	0.0015	-0.0230	-0.0291	0.0189	0.0086	-0.0686	0.0043	0.0075	0.0145	-0.0002	-0.0661
SL	0.0004	-0.0018	-0.0038	-0.0051	0.0063	0.1065	-0.0916	-0.0400	-0.4841	0.0242	0.0235	-0.0132	0.0152	-0.4632
GS	-0.0015	-0.0007	-0.0053	0.0002	0.0042	0.0942	-0.1037	-0.0292	-0.4024	0.0268	0.0147	0.0057	0.0116	-0.3855
WGS	-0.0004	0.0083	0.0011	0.0128	-0.0018	-0.0394	0.0280	0.1081	0.9506	0.0347	-0.1069	-0.0407	-0.0328	0.9217
TW	-0.0004	0.0071	0.0010	0.0199	0.0015	-0.0499	0.0404	0.0994	1.0335	0.0171	-0.1031	-0.0336	-0.0336	0.9992
BY	-0.0006	-0.0037	-0.0026	-0.0081	0.0008	-0.0213	0.0229	-0.0311	-0.1458	-0.1209	0.0878	0.0877	0.0069	-0.1281
HI	0.0003	0.0079	0.0023	0.0205	0.0013	-0.0196	0.0119	0.0905	0.8346	0.0832	-0.1277	-0.0804	-0.0063	0.8185
CTI	0.0020	0.0037	0.0034	0.0313	0.0026	0.0110	0.0046	0.0344	0.2710	0.0828	-0.0802	-0.1281	-0.0063	0.2320
WSP	-0.0006	0.0065	0.0014	0.0166	-0.0001	-0.0432	0.0321	0.0944	0.9240	0.0223	-0.0959	-0.0216	-0.0376	0.8985

DH: Days to heading, DM: Days to maturity, PH: Plant height, TP: Tillers/plant, FIN: 1st inter-node length, SL: Spike length, GS: Grains/spike, WGS: Weight of grains/spike, TW: Test weight, BY: biological yield, HI: harvest index, CTI: canopy temperature index, WSP: weight of spike/plant, GYP: grain yield/plant association with 4 yield contributing characters *viz.,* test weight (0.9992), weight of grains/spike (0.9217), weight of spike/plant (0.8985) and harvest index (0.7966). Selection for these characters can directly be followed for inherent yield improvement in wheat. Characters *viz*., spike length (-0.4632), grain/spike (-0.3855) and days to maturity (-0.3385) exhibited a significant negative association with grain yield, thereby, indicating that direct selection for these characters may not be helpful for improving the yield. Among the association of yield contributing characters themselves, weight of grain/spike has a negatively significant association with biological yield (-0.2872) indicating that the improvement in weight of grain/spike, if selection imparted may hamper the *per se* performance of that character. Present finding are in confirmation with Poor et al., [1], Khan et al., [12] and Singh et al., [10]

3.4 Path Analysis

Path coefficient analysis provides the information about the cause and effect situation in understanding the cause of association between two variables; it permitted the examination of the direct effect of various characters on yield as well as their indirect effects via other component traits. Thus though the estimates of direct and indirect effect, it determines the yield component. It also estimates of residual effects measure the role of other possible independent variables which are not included in the study.

3.5 Phenotypic Path Analysis

(Table 4) revealed that direct and indirect effects for various traits on grain yield revealed that weight of spike/plant exhibited highest positive direct effect on grain yield (0.9842) followed by canopy temperature index (0.4933), biological yield (0.3583), test weight (0.1360), grains/spike (0.0682), 1st internode length (0.0460) and harvest index (0.0308). Direct effect of days to heading on grain yield was negative (-0.0527) but recorded positive indirect effect on grain yield via canopy temperature index (0.1217) and tillers/plant (0.0196). Similarly days to maturity (-0.0715), plant height (-0.0995), tillers/plant (-0.1365), spike length (-0.0863) and weight of grain/plant (-0.0994) had negative direct effect on grain yield and positive indirect effect via several characters. The residual effect was recorded lower value (0.1233). Thus, indicates majority factors influencing the grain yield was considered in the present study. The present findings are in confirmation with Poor et al., [11], Khan et al. [12] and Singh et al., [10].

3.6 Genotypic Path Analysis

(Table 5) revealed that Direct and indirect effect for various traits on grain yield revealed that test weight registered highest positive direct effect on grain yield (1.0335) followed by weight of grains/spike (0.1081) and spike length (0.1065). Direct effect of harvest index on grain yield was negative (-0.1277) but it had a positive indirect effect via test weight (0.8346) on grain yield. Similarly, weight of spike/plant (-0.0376) also exhibited negative direct effect on grain yield and had a positive indirect effect via test weight (0.9240), weight of grain/spike (0.0944). Days to maturity exhibited negative direct effect (-0.0224) on grain yield and positive indirect effect via harvest index (0.0448). Grains/spike also showed negative direct effect (-0.1037) on grain yield. The residual effect value was showed very low (0.0352), thus, indicated majority factors influencing the grain yield was considered in the present study. The present findings are in confirmation with Poor et al., [11], Khan et al. [12] and Singh et al., [10].

4. CONCLUSION

The high heritability values coupled with high genetic advance were recorded for traits canopy temperature index, harvest index, spike length, grains per spike, test weight, grain yield per plant, tillers per plant, 1st inter-node length, weight of spike per plant, weight of grains per spike, biological yield and plant height, indicating that these characters are governed by additive gene effects and direct selection for these traits would be more effective for desired genetic improvement.

Correlation between grain yield/plant and four characters namely test weight (0.9895); weight of spike/plant (0.8565); weight of grains/spike (0.7921) and harvest index (0.7667) was found positive and significant and therefore selection for these characters can directly be followed for yield improvement in wheat. Path coefficient analysis revealed that some traits viz., test weight, weight of grain/spike and spike length exhibited highest positive direct effect and some traits have an indirect positive effect on grain yield and each trait must be given preference in selecting the superior types.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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