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Genetic Association Analysis for Morphological Traits in F_1 Generation of Wheat (*Triticum aestivum* L.)

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ABSTRACT: A diallel cross study comprising of ten bread wheat (*Triticum aestivum* L.) cultivars were carried out with its parents and F_1 progeny for correlation coefficient and path coefficient analysis of yield and its attributes in wheat. The present investigation revealed that grain yield was positively correlated with biological yield plant^{-1}, effective tillers plant^{-1}, number grains plant^{-1}, number of spikes plant^{-1}, harvest index, number of spikelets spike^{-1}, plant height and number of grains spike^{-1}. However, path analysis strongly pointed out the role of days to maturity, plant height, number of grains spike^{-1}, number of spikes plant^{-1}, biological yield plant^{-1}, harvest index and 1000 grain weight in the determination of grain yield per plant. Hence, more importance should be given to these traits while exercising selection. Based on correlation and path studies it was reported that biological yield plant^{-1}, number of spikes plant^{-1}, harvest index, plant height, effective tillers plant^{-1} and number of spikelets spike^{-1} could be used as important selection traits in order of merit to improve productivity during designing of suitable breeding programme in wheat.

Keywords: Genotype, Co-relation coefficient, Path coefficient, Hybrid, Wheat.

INTRODUCTION

Wheat is one of India's most important food grain crops which provides 20% of the total food calories of human requirement (Bhawsar, 1993). Both in terms of area and production, India is the second largest wheat growing country in the world. In acreage it is next to rice in India and in the world. From a meagre 5.6 million tons produced during 1947-48, marking an increase up to 98.61 million tons in 2019-20. Partly, this is the result of an increase in the area under wheat. However, the major part of this increase has resulted from increased productivity from 7 quintal to 33 quintal since freedom of the nation. This is primarily due to the introduction and development of dwarf Mexican high yielding wheat varieties. Madhya Pradesh, with a total area of 5.46 million hectares, is the state that produces the most wheat, with 17.58 million tonnes and 2627 kg/ha (Anonymous, 2020-21), but the increasing Indian population is the main challenge to the breeders. To feed this growing population, there is a need to improve genotypes to improve wheat yield potential per unit area. This could be accomplished by making the most of wheat genetic material's genetic potential.

Many of the crop improvement programmes aimed, in improvement of other characters in addition to yield, which were further related among themselves and to yield. As a result, studying the correlation between traits that affect yield can aid in the selection of traits that are linked to yield. As an example, the number of independent factors influencing a specific dependent variable such as yield. Correlation studies along with path analysis give a better understanding of the interaction of different characters with grain yield. Breeders should concentrate on producing productive wheat types by crossing high-yielding combination lines and choosing transgressive sergeants from the resulting hybrids. Correlation coefficient gives thought concerning the idea of quality activity and along these lines tells us about the adequacy of single plant selection. Investigation of the correlation coefficient and the path coefficient analysis may enhance the reproductive efficacy of the programme with the use of adequate measures for selection. Correlation coefficient analysis evaluates the combination of varieties of plant characters. We also identify the element traits on which form base of genetic selection and further improved production strategy. To find the level and direction of performance, association with traits contributes to performance and interactions between traits were identified. As a result, the current research was conducted to investigate the correlation and path coefficient analysis between yield attributing variables and quality traits in bread wheat.

MATERIAL AND METHODS

Three replications were used in a randomised block design experiment at ZARS, JNKVV, Powarkheda, Madhya Pradesh in black cotton soils during *Rabi* 2020-21. Each plot had two rows of two metres each, with a gap of 20 cm between rows and 10 cm between plants. Crop management was carried out using recommended agronomic procedures. Ten varieties and 45 crosses in diallel passion of wheat along with 2 checks were used in the experiment. The parents obtained from AICRP on wheat, ZARS Powarkheda and crosses were made in Rabi 2019-20 (Table 1).

Table 1: Details of parents.

Sr. No.	Genotype	Pedigree of parents	Source of parent
1.	GW -322	GW 173//GW 196	RARS, Vijapur
2.	MP-3382	CHOIX/STAR/3/HE1/3*CNO79//2*SERI/4/GW273	JNKVV, Jabalpur
3.	MP-3336	HD 2402/GW 173	JNKVV, Jabalpur
4.	HD-2967	ALD/COC/URESH/HD2160M/HD2278	IARI, New Delhi
5.	HI-1544	HINDI62/BOBWHITE/ CPAN2099	IARI, RWRS, Indore
6.	MP-3288	DOVE/BUC/DL 788-2	JNKVV, Jabalpur
7.	HD-3098	1455/2*PASTOR	IARI, New Delhi
8.	GW-173	TW 275/7/6/1LOK-1	RARS, Vijapur
9.	MP-4010	ANGOSTURA 88	RVSKVV, Gwalior
10.	GW 366	DL 802-3/GW 232	JAU, Junagadh

The data on 14 morphological traits *viz.*, days to 50% flowering, days to maturity, Plant height (cm), peduncle length(cm), effective tillers plant^{-1} , spike length (cm), number of spike plant^{-1}, number of spikelets spike^{-1}, number of grains spike^{-1}, biological yield plant^{-1} (g), number of grains per plant, 1000-grain weight (g), harvest index (%), grain yield plant^{-1} (g) were recorded.

Analysis of variance, correlation coefficients and path coefficients for the observations were calculated by Windostat version 9.2 form Indostat services, Hyderabad.

RESULTS AND DISCUSSIONS

A. Analysis of variance

The Analysis of variance for different quantitative traits of 55 entries along with the checks revealed that the component of variance with the genotypes was significant at 1% level of probability in all the traits namely, days to 50% flowering, days to maturity, plant height (cm), peduncle length (cm), effective tillers/plant, spike length (cm), number of spike/plant, no. of spikelets/spike, number of grains/spike, biological yield/plant (g), number of grains/plant, 1000-grain weight (g), harvest index (%) and grain yield/plant (g). The variation among these traits can be utilized in further breeding programme for improvement and selection of traits. Therefore, genes for such important trait may be utilized from other source such as from germplasm and other diverse genotypes.

Similar result was reported by Nagar *et al.* (2018). Correlation is a method for determining the relationship between various plant traits and determining which component characters might be used in a breeding programme to boost yield. On the basis of phenotypic expression, the breeder is always concerned with selecting superior genotypes. In the case of quantitative features, however, genotypes are modified by the environment, impacting phenotypic expression. Information on the nature and breadth of morphological character connection would be useful in establishing appropriate plant types, as well as improving yield, a complicated character for which direct selection is ineffective Bhushan *et al.* (2013).

For numerous yield and quality contributing factors, phenotypic and genotypic coefficients of association were calculated. Table 2 summarises the results of the current investigation. For almost all of the traits analysed, the phenotypic correlation coefficient is estimated to be larger than the genotypic correlation coefficient.

Grain yield reported significant positive correlation with biological yield/plant (0.721), number of grains/plant (0.423), effective tillers/plant (0.411), number of spikes/plant (0.383), number of spikelets/spike (0.262), plant height (0.276) and peduncle length (0.199), while, significant negative association was reported for 1000 grain weight (-0.248) and days to maturity (0.229). These results were in agreement with those of Ojha *et al*. (2018);

Oinam and Mehta (2020); Khanal *et al.* (2020); Barman *et al.* (2020).

Days to flowering showed significant positive correlation with spike length (0.616), plant height (0.564), days to maturity (0.476), number of spikelets/spike (0.379), peduncle length (0.214) and biological yield/plant (0.201). Days to maturity showed significant positive correlation with peduncle length (0.311), plant height (0.280), 1000-grain weight (0.192), number of spikes/plant (0.304), number of effective tillers/plant (0.272), while, significant negative correlation was reported for harvest index (-0.26) and grain yield/plant (-0.229). These results were quite in agreement with the findings of Khanal *et al*. (2020); Ojha *et al*. (2018); Ayer *et al*. (2017); Mecha *et al*. (2017); Sharma *et al*. (2017).

Plant height showed highly significant positive correlation with spike length (0.518) number of spikelets/spike (0.352), peduncle length (0.296) and number of grains/plant (0.228), while its negative correlation was reported for 1000-grain weight (-0.159). Peduncle length showed significant positive correlation with number of spikelets/spike (0.300), spike length (0.260) and biological yield/plant (0.256). Spike length showed significant positive correlation with number of spikelets/spike (0.335). The results were in agreement with the findings of Khanal *et al*. (2020); Reza *et al*. (2014); Oinam and Mehta (2020); Zeeshan *et al*. (2014); Pooja *et al*. (2018); Tarkeshwar *et al.* (2020); Kumar *et al*. (2018).

Number of grains/spike showed highly significant positive correlation with number of grains/plant (0.524), biological yield/plant (0.237), number of spikelets/spike (0.211), while, negative correlation was reported with 1000-grain weight (-0.345). Number of spikes per plant showed highly significant positive correlation with effective tillers/plant (0.922), number of grains/plant (0.837), and biological yield/plant (0.359). Number of spikelets /spike showed highly significant positive correlation with biological yield/plant (0.313), while, negative correlation was reported for 1000-grain weight (-0.343).The results were in agreement with the findings of Mecha *et al.* (2017); Sakuma and Schnurbusch (2020) for the number of grains per spike; Wolde *et al*. (2019); Khanal *et al*. (2020); Tabassum *et al*. (2018).

Effective tillers/plant showed positive significant correlation with number of grains/plant (0.811), biological yield/plant (0.308) and harvest index (0.179). The results were in agreement with the findings of Kumar *et al*. (2018); Khanal *et al*. (2020); Bhutto *et al*. (2016).

Biological yield/plant showed highly significant positive correlation with number of grains/plant (0.435), while, negative correlation was reported for harvest index (-0.333) and 1000-grain weight (-0.209).

The results were in agreement with the findings of Tarkeshwar *et al.* (2020); Bayisa and Amanuel (2021); Rani *et al*. (2021); Tabassum *et al*. (2018); Ozukum *et al*. (2019).

B. Path coefficient analysis between characters

Path coefficient analysis, on the other hand, is better for dividing direct and indirect reasons of correlation, as well as allowing breeders to compare component elements based on their proportional importance. The direct and indirect impacts of independent variables on dependent variables are shown via path analysis (Upadhyay, 2020). Using genotypic correlation coefficients of different yield contributing variables, path coefficient analysis was performed. The rest of the fourteen qualities are considered independent variables, with grain yield as the outcome variable. Table 3 shows the findings of the path analysis.

Biological yield/plant had positive association (0.731) with grain yield per plant and its direct effect was also positive and relatively large (1.089). Positive indirect effects were reported through effective tillers/plant (0.457), number of grains/spike (0.189), number of spikes/plant (0.161) and spike length (0.027). The maximum negative indirect effects were reported through number of grains/plant (-0.966) and minimum by harvest index (-0.149). These results agreed with the findings of Tabassum *et al*. (2018); Mecha *et al*. (2017).

The association of number of grains/plant with grain yield per plant was positive and low (0.438) but its direct effect on grain yield per plant was negative and large (-2.150). Its maximum positive indirect effect was due to biological yield/plant (0.489) and the minimum was through wet gluten (0.005). It reported negative indirect effects through 1000-grain weight (-0.014), days to maturity (-0.009) and days to flowering (-0.004).These results agreed with the findings of Kumar *et al.* (2018); Hamid *et al.* (2017); Khanal *et al.* (2020).

Effective tillers/plant had positive and relatively larger association (0.436) with grain yield/plant and its direct effect on grain yield/plant was highly positive (1.426). It reported maximum positive indirect effect *via* number of spikes/plant (0.420) and biological yield/plant (0.349) and minimum *via* spike length (0.001). It showed maximum negative indirect influence through number of grains/plant (-1.838) and days to maturity (-0.022). Similar findings were supported by Ozukum *et al.* (2019).

The correlation of number of spikes/plant with grain yield per plant was positive and relatively small in magnitude (0.399) but it had direct influence on grain yield per plant was positive and relatively large (0.429). It had maximum positive indirect effect was reported through effective tillers/plant (1.396) and biological yield/plant (0.408). It had negative indirect effect through number of grains/plant (-1.850) and days to maturity (-0.029). These results agreed with the findings of Hamid *et al.* (2017).

Table 2: Genotypic correlation coefficient (Above diagonal) and phenotypic correlations coefficient (below digonal between yield and yield attributing traits in bread wheat parents and cross combinations in wheat.

Traits	r	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	**rg**	**1.000**	0.490**	0.587**	0.247**	0.713**	0.157*	0.008	0.423**	-0.016	0.203**	-0.118	0.039	-0.112	0.150
	rp	**1.000**	0.476**	0.564**	0.214**	0.616**	0.154*	0.012	0.379**	-0.010	0.201**	-0.115	0.037	-0.107	0.150
C2	**rg**		**1.000**	0.293**	0.083	0.371**	-0.042	0.164*	-0.054	0.122	-0.081	-0.275**	0.051	0.205**	-0.229**
	rp		**1.000**	0.280**	0.066	0.311**	-0.039	0.153	-0.060	0.118	-0.079	-0.260**	0.045	0.192*	-0.229**
C3	**rg**			**1.000**	0.325**	0.603**	0.233**	0.022	0.402**	0.026	0.153	0.070	0.103	-0.174*	0.207**
	rp			**1.000**	0.296**	0.518**	0.228**	0.030	0.352**	0.036	0.149	0.057	0.107	-0.159*	0.207**
C4	**rg**				**1.000**	0.376**	0.027	-0.044	0.350**	-0.055	0.291**	-0.096	-0.025	0.021	0.199*
	rp				**1.000**	0.260**	0.028	-0.050	0.300**	-0.054	0.256**	-0.082	-0.022	0.026	0.199*
C5	**rg**					**1.000**	0.115	0.036	0.409**	0.006	0.155*	-0.103	0.079	0.002	0.073
	rp					**1.000**	0.098	0.038	0.335**	0.018	0.133	-0.091	0.055	0.007	0.073
C6	**rg**						**1.000**	0.046	0.229**	0.098	0.242**	-0.002	0.537**	-0.358**	0.188*
	rp						**1.000**	0.045	0.211**	0.091	0.237**	-0.006	0.524**	-0.345**	0.188*
C7	**rg**							**1.000**	-0.137	0.979**	0.375**	0.064	0.860**	0.017	0.383**
	rp							**1.000**	-0.108	0.922**	0.359**	0.062	0.837**	0.016	0.383**
C8	**rg**								**1.000**	-0.077	0.352**	-0.058	-0.009	-0.391**	0.262**
	rp								**1.000**	-0.073	0.313**	-0.058	-0.004	-0.343**	0.262**
C9	**rg**									**1.000**	0.321**	0.202**	0.855**	-0.015	0.411**
	rp									**1.000**	0.308**	0.179*	0.811**	-0.003	0.411**
C10	**rg**										**1.000**	-0.328**	0.450**	-0.218**	0.721**
	rp										**1.000**	-0.333**	0.435**	-0.209**	0.721**
C11	**rg**											**1.000**	0.054	-0.081	0.376**
	rp											**1.000**	0.052	-0.079	0.376**
C12	**rg**												**1.000**	-0.157*	0.423**
	rp												**1.000**	-0.145	0.423**
C13	**rg**													**1.000**	-0.248**
	rp													**1.000**	-0.248**
C14	**rg**														**1.000**
	rp														**1.000**

Where, r = correlation coefficient; rg and rp are genotypic and phenotypic correlation coefficients*, ** Significant at 5 and 1 per cent, respectively.

Table 3: Genotypic Path Matrix between yield and yield attributing traits in bread wheat parents and cross combinations.

Traits	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	**-0.105**	-0.087	0.077	0.018	0.122	0.122	0.004	-0.015	-0.023	0.221	-0.053	-0.084	-0.010	0.154*
C2	-0.052	**-0.178**	0.038	0.006	0.064	-0.033	0.070	0.002	0.174	-0.088	-0.125	-0.110	0.018	-0.237**
C3	-0.062	-0.052	**0.131**	0.023	0.104	0.181	0.009	-0.014	0.037	0.166	0.032	-0.221	-0.015	0.220**
C4	-0.026	-0.015	0.042	**0.072**	0.065	0.021	-0.019	-0.012	-0.079	0.316	-0.044	0.055	0.002	0.219**
C5	-0.075	-0.066	0.079	0.027	**0.172**	0.089	0.015	-0.014	0.008	0.169	-0.047	-0.169	0.000	0.090
C6	-0.017	0.007	0.030	0.002	0.020	**0.778**	0.020	-0.008	0.140	0.264	-0.001	-1.154	-0.032	0.195*
C7	-0.001	-0.029	0.003	-0.003	0.006	0.036	**0.429**	0.005	1.396	0.408	0.029	-1.850	0.002	0.399**
C8	-0.045	0.010	0.053	0.025	0.070	0.178	-0.059	**0.035**	-0.110	0.383	-0.026	0.020	-0.035	0.306**
C9	0.002	-0.022	0.003	-0.004	0.001	0.077	0.420	0.003	**1.426**	0.349	0.092	-1.838	-0.001	0.436**
C10	-0.021	0.014	0.020	0.021	0.027	0.189	0.161	-0.012	0.457	**1.089**	-0.149	-0.966	-0.019	0.731**
C11	0.012	0.049	0.009	-0.007	-0.018	-0.002	0.027	0.002	0.288	-0.357	**0.453**	-0.117	-0.007	0.372**
C12	-0.004	-0.009	0.013	-0.002	0.014	0.418	0.369	0.000	1.219	0.489	0.025	**2.150**	-0.014	0.438**
C13	0.012	-0.037	-0.023	0.002	0.000	-0.279	0.007	0.014	-0.022	-0.237	-0.037	0.336	**0.089**	-0.258**

*, ** Significant at 5 and 1 per cent, respectively.

C1- Days to 50% Flowering, C2- Days to Maturity, C3- Plant Height (cm), C4- Peduncle Length (cm), C5- Spike Length (cm), C6- Number of grains/spike, C7- Number of spikes/plant, C8- Number of spikelets/ spike, C9- Effective tillers/plant, C10- Biological yield/ plant (g), C11- Harvest index (%), C12- Number of grains/ plant, C13-1000-grain weight (g), C14- Hectolitre weight (g / litre), C15- Protein content (%), C16- Wet gluten (%), C17- Starch content(%), C14- Grain yield/ plant (g)

The correlation of harvest index with grain yield /plant was positive and relatively small in magnitude (0.372) but it had positive direct influence on grain yield/plant (0.453). It had maximum positive indirect effect through effective tillers/plant (0.288) followed by days to maturity (0.049) and number of spikes/plant (0.027). It had negative indirect effect through biological yield/plant (-0.357) and number of grains/plant (-0.117). These results agreed with the findings of Bhushan *et al.* (2013); Dayem *et al.* (2021); Abinasa *et al.* (2011); Dutamo *et al*. (2015).

The association of number of spikelets/spike with grain yield /plant was positive (0.306). The direct effect of number of spikelets/spike on grain yield /plant was negative and relatively small (-0.035). It reported maximum positive indirect influence through biological yield/plant (0.383) followed by number of grains/spike (0.178) and plant height (0.053) and the minimum through days to maturity (0.010). It had negative indirect influence *via* effective tillers/plant (-0.110). These results agreed with the finding of Khokhar *et al.* (2010).

The correlation of peduncle length with grain yield/plant was positive and relatively large in magnitude (0.219) but it had direct influence on grain yield /plant was positive and relatively small (0.072). It had maximum positive indirect effect was reported through biological yield/plant (0.316) followed by spike length (0.065) and number of grains/plant (0.055). It had negative indirect effect through effective tillers/plant (-0.079) and harvest index (-0.044).similar findings were also confirmed by Dayem *et al.* (2021); Baye *et al.* (2020); Sabit *et al.* (2017); Mecha *et al.* (2017). Selection based on these traits may be effective for yield improvement in bread wheat.

The correlation of plant height with grain yield per plant was positive and relatively large in magnitude (0.220) but it had direct influence on grain yield /plant which was positive and relatively small (0.131). It had maximum positive indirect effect through number of number of grains/spike (0.181) followed by biological yield/plant (0.166). It had negative indirect effect through number of grains/plant (-0.221) and days to flowering (-0.062). This was confirmatory with the findings of Poudel *et al.* (2021); Nagar *et al.* (2018).

The correlation of number of grains/spikes with grain yield /plant was positive and relatively small in magnitude (0.195) but it had direct influence on grain yield /plant was positive and relatively large (0.778). It had maximum positive indirect effect through number of biological yield/plant (0.264) followed by effective tillers/plant (0.140). It had negative indirect effect through number of grains/plant (-1.154) and 1000-grain weight (-0.032). This was in confirmatory with the findings of Baye *et al.* (2020).

The association of days to 50% flowering with grain yield/plant was positive and low (0.154) but its direct effect on grain yield/plant was negative and low (-0.105). It had maximum positive indirect effect was due to biological yield/plant (0.221) and the minimum was through starch content (0.000). It reported negative indirect effects through days to maturity (-0.087), number of grains/plant (-0.084) and harvest index (-0.053). This was in confirmatory with the findings of Ayer *et al.* (2017).

The association of 1000-grain weight with dependent variable was negative and relatively large (-0.258). It had direct effect was found in positive direction though it was relatively small (0.089). It reported maximum negative indirect effects *via* number of grains/spike (-0.279) followed by biological yield/plant (-0.237) and days to maturity and harvest index (-0.037). On the contrary it also reported positive indirect effects through number of grains/plant (0.336) and days to flowering (0.012).This was in confirmatory with the findings of Barman *et al.* (2020).

The association of days to maturity with dependent variable was negative and relatively large (-0.237). It had negative direct effect relatively small in magnitude (-0.178) on grain yield. It reported maximum negative indirect effects *via* harvest index (-0.125) followed by number of grains/plant (-0.110) and days to biological yield/plant (-0.088). On the contrary it also reported positive indirect effects through effective tillers/plant (0.174) and number of spikes/plant (0.070). Above findings were in conformity with results of Ayer *et al.* (2017); Barman *et al.* (2020).

CONCLUSION

The present investigation revealed that grain yield was positively correlated with biological yield/plant, effective tillers/plant, number of grains/plant, number of spikes/plant, harvest index, number of spikelets/spike, plant height, days to flowering and number of grains/spike. However, path analysis strongly pointed out the role of days to maturity, plant height, number of grains/spike, number of spikes/plant, biological yield/plant, harvest index, 1000-grain weight and wet gluten in the determination of grain yield/plant. Hence, more weightage should, therefore, be given to these traits while exercising selection. Based on correlation and path studies it was reported that biological yield plant^{-1}, number of spikes plant^{-1}, harvest index, plant height, effective tillersplant^{-1} and number of spikelets spike^{-1} could be used as important selection traits in order of merit to improve productivity during designing of suitable breeding programme in wheat.

FUTURE SCOPE

Correlation and path studies are beneficial for increasing yield by selecting yield-related features indirectly. The link between yield and its components identifies the most appropriate wheat improvement criteria. Wheat breeders will need this information in the future to follow wheat breeding programmes under irrigated environments.

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Conflict of Interest. None.

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