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Estimation of Genetic Variability, Correlation and Path Analysis for Yield and Some Yield Contributing Traits in Bread Wheat (*Triticum aestivum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted at the Student Instruction Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, during the rabi season of 2022–2023, to estimate the genetic variability, correlation, and path coefficient analysis of yield and its contributing traits in cross combination. Ten wheat cultivars were grown in a randomized block design with three replications.

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The analysis of variance revealed that the treatments were highly significant for all the characters. The higher magnitudes of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were recorded for grain yield, biological yield, harvest index and plant height. The high heritability in broad sense was estimated for all the characters except for day to 50% heading, flag leaf area (cm^2), number of leaves/main tiller, number of spikelets/ear and protein content (%).A high value of heritability suggests that it could be due to a higher contribution of genotypic components. High heritability associated with high genetic advantage as a percentage of the mean was found for plant height, harvest index, biological yield, and grain yield, indicating a predominance of additive gene action in the inheritance of these traits. The estimated correlation coefficients showed high direct genotypic and phenotypic correlations for days to 50% flowering, days to maturity, plant height, productive tillers/plant, test weight, biological yield, and harvest index. In contrast, flag leaf area (cm^2), number of leaves/main picks, number of kernels/spike, and seed hardiness were negatively correlated with grain yield. Path analysis showed that biological yield had the largest direct positive effect on grain yield, followed by harvest index, ear length, plant height, and days to 50%, indicating that these factors were the largest contributors to grain yield.

Keywords: Genetic variability; correlation coefficient; path analysis; Triticum aestivum.

1. INTRODUCTION

It is widely believed that wheat was the initial crop to be domesticated by humans on Earth [1]. Wheat *Triticum aestivum* L. em. Thell), is a self-pollinated crop belonging to the Poaceae family. It is considered one of the leading cereals in numerous countries, including India. In fact, wheat holds great significance as the most important food crop in India, serving as a major source of protein and energy. In terms of both land area and production, wheat ranks second after rice as the most crucial food crop in India. It has earned the title of the "King of cereals" due to its extensive cultivation, high productivity, and significant role in international food grain trade. Wheat can be cultivated in various climates, ranging from temperate, irrigated, and dry areas to warm, humid, and cold environments. It is consumed in diverse forms, such as bread, chapatti, porridge, flour, and suji. Wheat contains relatively high levels of niacin and thiamin, which are primarily responsible for the presence of a special protein known as "Gluten." This protein is of immense importance as it provides the structural framework and spongy texture to bread and baked goods. Globally, wheat is grown across 224.49 million hectares, with an estimated annual production of 792.4 million tones [2]. In India, the total land area dedicated to wheat cultivation in 2021-22 was 30.47 million hectares, resulting in a production of 106.84 million tonnes. In Uttar Pradesh (U.P.), specifically, the cultivated area for wheat in the same year was 9.54 million hectares, yielding a production of 32.74 million tonnes [3]. However, with the expected increase in demand for wheat, there is a need to enhance productivity. Understanding genetic variability, heritability, correlation coefficients, and other related parameters can aid in improving grain yield through targeted selection of specific traits and their relationship with overall productivity. Therefore, the present study aims to assess the variability and heritability in wheat, with the goal of utilizing this information in selection programs to enhance productivity in future wheat genotypes.

2. MATERIALS AND METHODS

The experimental material comprised of 10 diverse wheat cultivars. These cultivars were cultivated in a randomized block design with three replications at the Student Instruction Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, during the rabi season of 2022-23. Geographically, this place is located between 25^0 28’ and 26^0 58’ N latitude, 79^0 31’ and 80^0 34’ E longitudes and an altitude of 125.9 m above from mean sea level. This falls in sub-tropical climatic zone. The soil type is sandy loam. The annual rainfall is about 1270 mm. The climate of district Kanpur is semi-arid with hot summer and cold winter.Each cultivar was grown in a single row plot measuring 4 meters in length, with a distance of 23 centimeters between rows. The plants within each plot were spaced 10 centimeters apart. The recommended agricultural practices and techniques were followed to ensure proper crop growth. Various quantitative characteristics of the wheat plants were recorded as observations. These characteristics included the number of days to reach 50% heading, the number of days to maturity, plant height in centimeters, flag leaf area in square centimeters, number of leaves on the main tiller, number of productive tillers per plant, ear length in centimeters, number of spikelets per ear, number of grains per ear, biological yield per plant in grams, grain yield per plant in grams, harvest index as a percentage, 1000-grain weight in grams, seed hardness, and protein content as a percentage. For each replication and for all characteristics except for the number of days to 50% heading and days to maturity, five randomly selected competitive plants were recorded. The harvest index value was calculated using the formula provided by Donald and Humblin [4]. The mean performance of each genotype was analyzed statistically. The significance of each characteristic was tested through analysis of variance, following the methodology suggested by Panse and Sukhatme [5]. Genotypic and phenotypic coefficients of variation (GCV and PCV) were calculated using the formula proposed by Burton [6]. The heritability in broad sense (h^2) was determined using the method described by Burton and Vane [7]. The genetic advance was calculated based on the formula provided by Johnson et al. [8]. Correlation coefficient and path coefficient were determined using the methods suggested by Al-Jibouri et al. (1958) and Dewey and Lu [9], respectively.

3. RESULTS AND DISCUSSION

The results from the analysis of variance (Table 1) indicated that all the treatments had a significant impact on the various characteristics studied. Among these characteristics, the highest value was observed for biological yield, followed by plant height and grain yield. On the other hand, the number of leaves per main tiller was found to be the lowest. These findings suggest that the selected genotypes exhibited genetic variability, with a notable amount of variation existing among them. Similar results were previously reported by Asif et al. [10], Tripathi et al. [11], Jaiswal et al. [12], Elahi et al. [13], and Almutairi et al. [14].

The experimental material was analyzed to determine the genotypic (GCV) and phenotypic (PCV) coefficients of variation for all the studied traits. The results, displayed in Table 2, revealed that biological yield, plant height, harvest index, and grain yield had the highest magnitudes of GCV and PCV. Specifically, biological yield had GCV and PCV values of 17.51 and 45.01, plant height had values of 11.21 and 11.82, harvest index had values of 7.95 and 19.75, and grain yield had values of 7.89 and 50.48, respectively. On the other hand, the traits such as number of spikelets per spike, days to 50% heading, days to maturity, productive tillers per plant, and number of grains per ear exhibited the lowest genotypic and phenotypic coefficients of variation. This suggests that there is sufficient variability in these traits and therefore potential for genetic improvement through selective breeding. Notably, the phenotypic coefficient of variation (PCV) was consistently higher than the genotypic coefficient of variation (GCV) across all studied traits. These findings were agreement with Yausaf et al. [15], Tripathi et al. [11], Ashfaq et al. [16], Sarfraz et al. [17] and Arya et al. [18]. Determining the heritable portion of variation is not solely dependent on these values. The heritability of genetic variability passed on from parents to offspring is a reflection of the proportion of genetic variability, as stated by Lush [19]. With regards to various characteristics, high heritability in the broad sense has been estimated, except for days to 50% heading, flag leaf area, number of leaves per main tiller, and protein content. Among these characteristics, grain yield per plant has the highest estimates, followed by biological yield, productive tillers per plant, plant height, and seed hardness (as shown in Table 2). A high value indicates that the heritability may be attributed to a greater contribution of genotypic components. Similar results for high heritability estimates were reported by, Rasal et al. [20], Yausaf et al. [15], Molla and Thomas [21] and Tripathi et al. [11].

The estimates of heritability become more advantageous when they are expressed in terms of genetic advance. Johnson et al. [8] proposed that the estimation of heritability lacks practical value without genetic advance and emphasized the concurrent utilization of genetic advance alongside heritability. Hanson [22] asserted that heritability and genetic advance are two complementary concepts. Taking this into consideration, traits such as biological yield, seed hardness, productive tillers per plant, harvest index, and grain yield demonstrated a predominance of additive gene action in their expression, as indicated by high heritability coupled with high genetic advance as a percentage of the mean. On the other hand, plant height, harvest index, and grain yield exhibited a predominance of both additive and non-additive gene action, as evidenced by high heritability coupled with moderate genetic advance. Consequently, these traits can be enhanced through mass selection and other breeding methods based on progeny testing.

Table 1. Analysis of variance for parents and F_1s for 15 Characters in a 10 parent diallel crosses to wheat (*Triticumaestivum*L.)

	D.F.	Days to 50% Heading	Days to Maturity	Plant Height (cm)	Flag Leaf Area (cm2)	Number of Leaves/Main Tiller	Productive tillers/plant	Ear length (cm)
Replicates	2	2.68	0.65	10.03	5.36	0.077	0.16	0.12
Treatments	54	4.63**	16.08**	68.13**	3.38**	0.043**	3.29**	1.01**
Error	108	2.00	2.20	3.97	1.76	0.029	0.15	0.17
Total	164	3.16	6.75	26.29	2.34	0.034	1.19	0.45
Number of spikelets/ear	**Number of grains/ear**		**Biological yield/plant (g)**	**Harvest index (%)**	**1000-grain weight (g)**	**Seed hardness**	**Protein content (%)**	**Grain yield/plant (g)**
0.29	1.30		20.55	0.98	4.92	0.17	0.02	2.46
2.19**	15.16**		144.15**	44.12**	17.89**	3.77**	2.27**	28.45**
0.65	3.50		3.21	5.44	1.82	0.27	0.70	0.43
1.15	7.31		49.83	18.12	7.15	1.42	1.21	9.68

**, ** significant at 5% and 1% level, respectively*

Table 2. Direct selection parameters for 15 characters in 10 parent diallel cross in wheat (*Triticumaestivum*L.)

Genotypes	Mean	Heritability (%)	GA	GA% mean	GCV (%)	PCV (%)
Days to 50% heading	84.95	30.52	1.07	1.26	1.37	1.61
Days to maturity	124.96	67.73	3.65	2.92	4.67	3.74
Plant height (cm)	94.84	84.34	8.75	9.22	11.21	11.82
Flag leaf area (cm2)	24.28	23.52	0.73	3.03	0.94	3.88
Number of leaves/main tiller	5.34	13.32	0.05	0.94	0.06	1.21
Productive tillers/plant	8.02	87.39	1.97	24.58	2.53	31.50
Ear length (cm)	10.08	61.70	0.85	8.46	1.09	10.84
Number of spikelets/ear	19.97	44.37	0.99	4.93	1.26	6.32
Number of grains/ear	50.25	52.63	2.95	5.86	3.78	7.51
Biological yield/plant (g)	38.90	93.61	13.66	35.12	17.51	45.01
Harvest index (%)	40.25	70.33	6.20	15.41	7.95	19.75
1000-grain weight (g)	44.46	74.64	4.12	9.26	5.28	11.87
Seed hardness	8.65	81.19	2.00	23.17	2.57	29.69
Protein content (%)	12.38	42.56	0.97	7.84	1.24	10.05
Grain yield/plant (g)	15.63	95.60	6.16	39.39	7.89	50.48

Table 3. The estimates of genotypic and phenotypic correlation coefficient among 15 characters in bread wheat

Parent /Hybrids		Days to 50% heading	Days to maturity	Plant height (cm)	Flag leaf area (cm2)	Number of leaves/ main tiller	Productive tillers/ plant	Ear length (cm)	Number of spikelets/ear	Number of grains/ear	Biological yield/plant (g)	Harvest index (%)	1000-grain weight (g)	Seed hardness	Protein content (%)	Grain yield/plant (g)
Days to 50% heading	G	1.000	0.161*	0.354**	-0.408**	-0.284**	0.157*	0.030	0.327**	0.034	0.356**	-0.233**	0.591**	-0.402**	0.399**	0.230**
	P	1.000	-0.089	0.213**	-0.193*	-0.074	0.050	-0.076	0.100	0.082	0.214**	-0.113	0.277**	-0.241**	0.154*	0.136
Days to maturity	G			0.162*	-0.216**	-0.094	0.510**	0.350**	0.205**	0.156*	0.520**	0.096	0.449**	0.004	0.424**	0.512**
	P			0.105	-0.082	-0.038	0.391**	0.205**	0.076	0.050	0.390**	0.113	0.313**	0.025	0.231**	0.412**
Plant height (cm)	G				-0.312**	0.813**	0.064	0.113	0.339**	-0.128	0.141	0.146	0.287**	-0.176*	0.361**	0.200**
	P				-0.164*	0.241**	0.057	0.069	0.213**	-0.079	0.152	0.079	0.247**	-0.156*	0.296**	0.186*
Flag leaf area (cm2)	G					0.046	-0.196*	-0.332**	-0.757**	-0.314**	-0.362**	0.043	-0.583**	0.675**	-0.385**	-0.299**
	P					-0.071	-0.107	-0.234**	-0.382**	-0.250**	-0.184*	0.076	-0.185*	0.278**	-0.171*	-0.119
leaves/ main tiller	G						-0.456**	0.296**	0.534**	0.047	-0.356**	0.357**	-0.161*	-0.175*	-0.260**	-0.154*
	P						-0.184*	0.081	0.080	0.131	-0.117	0.022	-0.079	0.014	0.002	-0.090
Productive tillers/plant	G							0.124	0.120	0.045	0.785**	0.026	0.373**	-0.197*	0.395**	0.719**
	P							0.119	0.083	0.021	0.720**	0.016	0.294**	-0.178*	0.220**	0.665**
Ear length (cm)	G								0.717**	0.656**	0.053	-0.060	0.030	0.122	0.137	0.023
	P								0.579**	0.449**	0.013	0.003	-0.031	0.094	0.169*	0.013
Number of spikelets/ear	G									0.537**	0.077	-0.042	0.162*	-0.301**	0.073	0.038
	P									0.439**	0.057	-0.068	0.040	-0.177*	0.030	0.011
Number of grains/ear	G										-0.112	-0.021	-0.076	-0.084	-0.012	-0.124
	P										-0.080	-0.082	-0.122	-0.042	0.025	-0.121
Biological yield/ plant (g)	G											-0.057	0.715**	-0.211**	0.409**	0.884**
	P											-0.136	0.595**	-0.191*	0.235**	0.846**
Harvest index (%)	G												0.040	0.164*	0.122	0.412**
	P												0.027	0.150	0.131	0.405**
1000-	G													-0.319**	0.407**	0.665**

Parent /Hybrids		Days to 50% heading	Days to maturity	Plant height (cm)	Flag leaf area (cm2)	Number of leaves/ main tiller	Productive tillers/ plant	Ear length (cm)	Number of spikelets/ear	Number of grains/ear	Biological yield/plant (g)	Harvest index (%)	1000-grain weight (g)	Seed hardness	Protein content (%)	Grain yield/plant (g)
grain weight (g)																
	P													-0.239**	0.218**	0.563**
Seed hardness	G														-0.315**	-0.098
	P														-0.168*	-0.083
Protein content (%)	G															0.416**
	P															0.274**
Grain yield/plant (g)	G															1.000
	P															1.000

**, ** significant at 5% and 1% level, respectively*

Table 4. Direct and Indirect Effects of Different Characters on Grain Yield per Plant in Bread Wheat

Parent/ Hybrids		Days to 50% heading	Days to maturity	Plant height (cm)	Flag leaf area (cm2)	Number of leaves/main tiller	Productive tillers/ plant	Ear length (cm)	Number of spikelets/ ear	Number of grains/ear	Biological yield/ plant (g)	Harvest index (%)	1000-grain weight (g)	Seed hardness	Protein content (%)	Grain yield/plant (g)
Days to 50% heading	G	0.1392	0.0087	0.0629	0.0942	0.0372	-0.0073	0.0090	-0.1201	-0.0029	0.3466	-0.1354	-0.1374	0.0335	-0.0986	0.230**
	P	0.0012	0.0007	0.0020	-0.0012	-0.0003	-0.0001	-0.0006	-0.0007	-0.0001	0.1978	-0.0599	0.0019	-0.0027	-0.0019	0.136
Days to maturity	G	0.0224	0.0539	0.0287	0.0500	0.0123	-0.0239	0.1055	-0.0754	-0.0134	0.5058	0.0560	-0.1044	-0.0003	-0.1047	0.512**
	P	-0.0001	-0.0077	0.0010	-0.0005	-0.0002	-0.0008	0.0017	-0.0005	-0.0001	0.3605	0.0597	0.0021	0.0003	-0.0029	0.412**
Plant height (cm)	G	0.0493	0.0087	0.1775	0.0721	-0.1067	-0.0030	0.0341	-0.1243	0.0110	0.1375	0.0851	-0.0666	0.0147	-0.0891	0.200**
	P	0.0003	-0.0008	0.0092	-0.0010	0.0010	-0.0001	0.0006	-0.0014	0.0001	0.1406	0.0419	0.0017	-0.0018	-0.0037	0.186*
Flag leaf area (cm2)	G	-0.0568	-0.0117	-0.0555	-0.2308	-0.0060	0.0092	-0.1000	0.2780	0.0270	-0.3519	0.0252	0.1354	-0.0563	0.0950	-0.299**
	P	-0.0002	0.0006	-0.0015	0.0060	-0.0003	0.0002	-0.0019	0.0026	0.0004	-0.1698	0.0404	-0.0013	0.0031	0.0022	-0.119
leaves/ main tiller	G	-0.0395	-0.0051	0.1443	-0.0106	-0.1313	0.0213	0.0893	-0.1960	-0.0041	-0.3467	0.2077	0.0373	0.0146	0.0643	-0.154*
	P	-0.0001	0.0003	0.0022	-0.0004	0.0043	0.0004	0.0007	-0.0005	-0.0002	-0.1076	0.0119	-0.0005	0.0002	0.0000	-0.090
Productive tillers/plant	G	0.0218	0.0275	0.0114	0.0452	0.0598	-0.0468	0.0374	-0.0439	-0.0039	0.7633	0.0152	-0.0867	0.0164	-0.0975	0.719**
	P	0.0001	-0.0030	0.0005	-0.0006	-0.0008	-0.0020	0.0010	-0.0006	0.0000	0.6648	0.0084	0.0020	-0.0020	-0.0028	0.665**
Ear length (cm)	G	0.0042	0.0189	0.0201	0.0766	-0.0389	-0.0058	0.3012	-0.2633	-0.0564	0.0518	-0.0348	-0.0069	-0.0102	-0.0339	0.023
	P	-0.0001	-0.0016	0.0006	-0.0014	0.0003	-0.0002	0.0080	-0.0039	-0.0008	0.0119	0.0017	-0.0002	0.0011	-0.0021	0.013
Number of spikelets/ear	G	0.0456	0.0111	0.0601	0.1748	-0.0701	-0.0056	0.2161	-0.3670	-0.0462	0.0746	-0.0246	-0.0376	0.0251	-0.0180	0.038
	P	0.0001	-0.0006	0.0020	-0.0023	0.0003	-0.0002	0.0047	-0.0067	-0.0007	0.0525	-0.0358	0.0003	-0.0020	-0.0004	0.011
Number of grains/ear	G	0.0048	0.0084	-0.0226	0.0725	-0.0062	-0.0021	0.1976	-0.1973	-0.0859	-0.1091	-0.0121	0.0176	0.0070	0.0030	-0.124
	P	0.0001	-0.0004	-0.0007	-0.0015	0.0006	0.0000	0.0036	-0.0030	-0.0017	-0.0735	-0.0431	-0.0008	-0.0005	-0.0003	-0.121
Biological yield/ plant (g)	G	0.0496	0.0280	0.0251	0.0835	0.0468	-0.0367	0.0160	-0.0281	0.0096	0.9730	-0.0331	-0.1662	0.0176	-0.1009	0.884**
	P	0.0003	-0.0030	0.0014	-0.0011	-0.0005	-0.0014	0.0001	-0.0004	0.0001	0.9232	-0.0717	0.0041	-0.0022	-0.0030	0.846**
Harvest index (%)	G	-0.0324	0.0052	0.0260	-0.0100	-0.0469	-0.0012	-0.0181	0.0155	0.0018	-0.0555	0.5812	-0.0094	-0.0137	-0.0301	0.412**
	P	-0.0001	-0.0009	0.0007	0.0005	0.0001	0.0000	0.0000	0.0005	0.0001	-0.1252	0.5289	0.0002	0.0017	-0.0017	0.405**
1000-grain weight (g)	G	0.0823	0.0242	0.0509	0.1345	0.0211	-0.0175	0.0090	-0.0594	0.0065	0.6959	0.0234	-0.2323	0.0266	-0.1005	0.665**
	P	0.0003	-0.0024	0.0023	-0.0011	-0.0003	-0.0006	-0.0003	-0.0003	0.0002	0.5491	0.0144	0.0068	-0.0027	-0.0028	0.563**
Seed hardness	G	-0.0559	0.0002	-0.0313	-0.1559	0.0229	0.0092	0.0369	0.1106	0.0072	-0.2053	0.0953	0.0740	-0.0834	0.0779	-0.098
	P	-0.0003	-0.0002	-0.0014	0.0017	0.0001	0.0004	0.0008	0.0012	0.0001	-0.1767	0.0794	-0.0016	0.0113	0.0021	-0.083
Protein content (%)	G	0.0556	0.0229	0.0641	0.0888	0.0342	-0.0185	0.0413	-0.0268	0.0011	0.3977	0.0708	-0.0946	0.0263	-0.2469	0.416**
	P	0.0002	-0.0018	0.0027	-0.0010	0.0000	-0.0004	0.0014	-0.0002	0.0000	0.2165	0.0695	0.0015	-0.0019	-0.0127	0.274**

Parent/ Hybrids		Days to 50% heading	Days to maturity	Plant height (cm)	Flag leaf area (cm2)	Number of leaves/main tiller	Productive tillers/ plant	Ear length (cm)	Number of spikelets/ ear	Number of grains/ear	Biological yield/ plant (g)	Harvest index (%)	1000-grain weight (g)	Seed hardness	Protein content (%)	Grain yield/plant (g)
Grain yield/plant (g)	G	0.0556	0.0229	0.0641	0.0888	0.0342	-0.0185	0.0413	-0.0268	0.0011	0.3977	0.0708	-0.0946	0.0263	-0.2469	0.416**
	P	0.0002	-0.0018	0.0027	-0.0010	0.0000	-0.0004	0.0014	-0.0002	0.0000	0.2165	0.0695	0.0015	-0.0019	-0.0127	0.274**

Residual effect-0.0052 (G)
Residual effect - 0.0090 (P)

Similar results in wheat were also reported by Prasad et al [23], Kamboj [24], Payal et al. [25], Sen and Toms [26], Tripathi et al. [11], Rathwa et al. [27] and Malbhage et al. [28].

The correlation coefficient analysis assesses fifteen inherent relationships between different plant characteristics and identifies the specific traits that can be targeted for genetic enhancement in yield. The breeder consistently prioritizes the selection of superior genotypes based on phenotypic manifestation. Nonetheless, the genotypes of quantitative traits are impacted by the environment, thereby affecting their phenotypic expression. Acquiring knowledge about the nature and magnitude of association among morphological traits would be advantageous in the development of suitable plant types, alongside the enhancement of yield, which is a multifaceted trait not amenable to direct selection [29-31]. Consequently, a more formal tone has been employed to convey the aforementioned information.

The highest direct genotypic and phenotypic correlations were observed in the biological yield (0.884 and 0.846), productive tillers per plant (0.719 and 0.665), test weight (0.665 and 0.563), days to maturity (0.512 and 0.412), and harvest index (0.412 and 0.405), as estimated in Table 3. Conversely, there were negative direct correlations with grain yield for flag leaf area (-0.299 and -0.119) and number of leaves per main tiller (-0.154 and -0.090). Additionally, it was found that genotypic correlation coefficients were higher in the negative direction compared to their corresponding phenotypic correlation coefficients. This is likely a result of the modifying effect of the environment. The presence of a high genotypic correlation indicates an inherent relationship between the studied traits. However, there was no significant direct genotypic correlation observed for ear length and number of spikelets per ear. Consequently, it can be concluded that selecting for higher yield based on the aforementioned traits would be a reliable approach similar findings were also reported by Khan et al. [32], Ayccek and Yldrm [33], Prasad et al. [23], Payal et al. [26], Dharamandra and Singh [34], Tripathi et al. [11], El- Mohsen [35] and Singh et al. [36]. Rathod et al. [37] and Kamani et al. [38].

The biological yield per plant exhibited a positive correlation with plant height, days to maturity, productive tillers per plant, and test weight. Conversely, the flag leaf area, number of leaves per main tiller, and harvesting index displayed a negative association at the genotypic level (Table 4). Additionally, test weight demonstrated a positive correlation with biological yield per plant, seed hardness, and number of grains per ear. Conversely, plant height at the genotypic level indicated a negative and significant correlation with the number of leaves per main tiller and spikelets per ear. On the other hand, the number of leaves per main tiller exhibited a positive and significant correlation with productive tillers per plant at both genotypic and phenotypic levels. Productive tillers per plant displayed a negative and significant correlation with the number of spikelets per ear, but showcased a positive and significant association with plant height. These findings align with the results of Ashfaq et al. [39], Shukla et al. [40], Prasad et al. [24], Raiz-ud-Din et al. [41], and Tripathi et al. [11]. Hama et al. [42] and Dhanda et al. [43] also support these conclusions.

Shrivastava and Sharma [44] proposed that only direct yield components should be used for path analysis. Path biological yield (0.973) exhibited the highest direct positive effect on grain yield, followed by harvest index (0.5812), ear length (0.3012), plant height (0.1775), and days to maturity (0.539). These factors were identified as the main contributors to grain yield. Similar findings were reported by Payal et al. [25] and Tripathi et al. [11]. Gupta et al. [45], Hama et al. [42], and Bhushan et al. [46] observed that biological yield, harvest index, test weight, and productive tillers per plant made the greatest contributions towards grain yield. However, flag leaf area (-0.2308), number of leaves per main tiller (-0.1313), test weight (-0.2323), seed hardness (-0.0834), and protein content (-0.2469) had a direct negative effect on grain yield per plant. These negative effects are consistent with the findings of Bhutta et al. [47] and Singh et al. [36].

4. CONCLUSION

An analysis of variance indicated that the mean squares due to genotypes were highly significant for all the characters under study. Furthermore, correlation studies indicated significant positive correlations between grain yield and productive tiller per plant, harvest index, biological yield, and 1000-grain weight. Moreover, productive tiller per plant and biological yield were found to have positively high direct effects on grain yield. This suggests that selecting these traits under normal conditions would be effective for improving grain yield. Therefore, based on the present findings, 1000-grain weight, productive tiller per plant, biological yield, and harvest index can be utilized as suitable criteria for selecting high yielding genotypes. However, path coefficient analysis is more useful for partitioning direct and indirect causes of correlation and also enables breeders to compare the component factors based on their relative contributions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sootaher JK, Abro TF, Soomro ZA, Soothar MK, Baloch TA, Menghwar KK, Kachi M, Mastoi MA, Soomro TA. Assessment of genetic variability and heritability for grain yield and its associated traits in F2 populations of bread wheat (*Triticum aestivum* L.). Pure and Applied Biology. 2020;9(1):36-45.
2. United States Department of Agriculture. 2020-21.
3. Agricultural Statistics at a Glance; 2022.
4. Donald CM and Humblin J. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Advance Agronomy. 1976;28:361-405.
5. Panse VG and Sukhatme PV. Statistical Methods of Agricultural Workers. 2nd Endorsement, ICAR Publication, New Delhi, India. 1967:381.
6. Burton GW. Quantitative inheritance of grasses. In: Proceedings 6th International Grassland Congress. 1952;1:273-283.
7. Burton GW and Vane de EH. Estimating heritability in tall fescue (*Festuca arundinacea L*.) from replicated clonal material. Agronomy of Journal. 1953;45: 478-481.
8. Johnsan HW, Robinson HF and Camstock. Estimate of genetic and environmental variability in soyabean. Agronomy Journal 1955;47:314-318
9. Dewey DR and Lu KH. A correlation and path coefficient analysis of component of crested wheatgrass seed production. Journal of Agronomy. 1959;51:515-518.
10. Asif M, Mujahid MY, Kisana NS, Mustafa SZ and Ahmad I. Heritability, genetic variability and path coefficient of some traits in spring wheat. Sarhad Journal of Agriculture. 2004;20:87-91.
11. Tripathi SN, Shailesh Marker, Praveen Pandey, Jaiswal KK and Tiwari DK. Relationship between some morphological and physiological traits with grain yield in bread wheat (*Triticum aestivum* L.em.Thell.). Trends in Applied Science Research. 2011;6(9):1037-1045.
12. Jaiswal A, Singh V, Lal K, Prasad D, Yadav K, Yadav VP. Study on genetic variability and divergence under sodic soil in indigenous lines of wheat (*Triticum aestivum* L. em. Thell). Journal of Pharmacognosy and Phytochemistry. 2019;8(3):1752-1756.
13. Elahi T, Pandey S, Shukla RS. Genetic variability among wheat genotypes based on Agro-morphological traits under restricted irrigated conditions. Journal of Pharmacognosy and Phytochemistry. 2020;9(3):801-805.
14. Almutairi MM. Genetic parameters estimation for some wild wheat species and their F1 hybrids grown in different regions of Saudi Arabia Saudi. Journal of Biological Sciences. 2021;29(2022):521-525
15. Yousaf Ali, Atta BM, Javed Akhter, Monneveux P and Zahid Lateef. Genetic variability, association and diversity studies in wheat (*Triticum aestivum* L.) germplasm. Pakistan Journal of Botany. 2008;40(5): 2087-2097.
16. Ashfaq S, Ahmad HM, Awan SI, Kang SA, Sarfraz M, Ali MA. Estimation of genetic variability, heritability and correlation for some morphological traits in spring wheat. Journal of Biology, Agriculture and Healthcare. 2014;4(5):10-16.
17. Sarfraz Z, Shah MM, Iqbal MS. Genetic variability, heritability and genetic advance for agronomic traits among a-genome donor wheat genotypes. J. Agric. Res. 2016;54(1):15-20.
18. Arya VK, Singh J, Kumar L, Kumar R, Kumar P, Chand P. Genetic variability and diversity analysis for yield and its components in wheat (*Triticum aestivum* L.). Indian J. Agric. Res. 2017;51(2): 128-134.
19. Lush JL. Heritability of quantitative characters in farm animals. Herbicides. 1949;35:356-357.
20. Rasal PN, Bhoite KD and Godekar DA. Genetic variability and genetic advance in

durum wheat. Journal of Maharashtra Agriculture University. 2008;33:102-103.

21. Molla Assefa and Thomas Lemma. Genetic analysis of wheat varieties for yield and its components. Annals of Biology. 2009;25(1):31-34.
22. Hanson WD, Robinson HF. Statistical genetics and plant breeding. In *Symposium on Statistical Genetics and Plant Breeding (1961: North Carolina State College).*. National Academy of Sciences-National Research Councl; 1963.
23. Prasad J, Kerketta V, Prasad KD and Verma AK. Study of genetic parameters under different environment conditions in wheat (*Triticum aestivum* L.) Birsa Agricultural University, Journal of Research. 2006;18(1):135-140.
24. Kamboj RK. Estimating parameters of variability, adaptive value and selection coefficient in bread wheat (*Triticum aestivum* L.) under salinity and drought stress conditions. Agriculture Science Digest. 2007;27: 30-33.
25. Payal Saxena, Rawat RS, Verma JS and Meena BK. Variability and association analysis for yield and quality traits in wheat. Pantnagar Journal of Research. 2007;5(2):85-92.
26. Sen Chaitali and Toms Bini. Character association and component analysis in wheat (*Triticum aestivum* L.). Crop Research, Hisar. 2007;34(1/3):166-170.
27. Rathwa HK, Pansuriya AG, Patel JB, Jalu RK. Genetic variability, heritability and genetic advance in durum wheat (*Triticum durum* Desf.). Int. J. Curr. Microbiol. App. Sci., 2018;7(1):1208-1215.
28. Malbhage AB, Malbhage MM, Shekhawat VS, Mehta VR. Genetic variability, heritability and genetic advance in durum wheat (*Triticum durum* L.). Journal of Pharmacognosy and Phytochemistry. 2020;9(4):3233-3236.
29. Robinson HR (Eds.). National Academy of Science, Washington DC, USA125-140.
30. Effect of temperature on development and grain formation in spring wheat. Pakistan Journal of Botany 42(2): 899-906.
31. Pawar SV, Patil SC, Naik RM and Jombhal VM. Genetic variability and heritability in wheat. Journal of Maharashtra Agriculture University. 2002;27:324-325.
32. Khan AJ, Azam F, AE A, Tariq M and Amin M. Inter-relationship and path coefficient analysis for biometric traits in drought tolerant wheat *(Triticum aestivum L.).* Asian Journal of Plant Science 2005;4: 540-543.
33. Ayccek M and Yldrm T. Path coefficient analysis of yield and yield components in bread wheat (*Triticum aestivum* L.). Pakistan Journal of Botany 2006;38(2): 417-424.
34. Dharmendra S and Singh KN. Variability analysis for yield and yield attributes of bread wheat under salt affected condition. Wheat Information Service. 2010;110:35-39.
35. El-Mohsen AA, Hegazy SRA and Taha MH. Genotypic and phenotypic interrelationships among yield and yield components in Egyptian bread wheat genotypes. Journal of Plant Breeding and Crop Science. 2012;4(1):9-16.
36. Singh BN, Soni SK, Archana Srivastav and Yadav VK. Analysis of yield components and theirassociation for selection of parent to architecture model plant type in bread wheat (*Triticum aestivum* L.) to saline soil. Environment and Ecology 2012;30(1):106-109.
37. Rathod ST, Pole SP, Gawande SM. Correlation and path analysis for quality and yield contributing traits in wheat (*Triticum aestivum* L.). Int. J. Curr. Microbiol. App. Sci., 2019;8(6):456-461.
38. Kamani DL, Babariya CA, Marviya PB. Correlation coefficient and path coefficient analysis for yield components in wheat (*Triticum aestivum* L.). Int. J. Pure App. Biosci. 2017;5(5): 545-552.
39. Ashfaq M, Khan AS and AE Z. Association of morphological traits with grain yield in wheat *(Triticum aestivum* L*.).* International Journal of Agricultural Biology 2003;5:262-264.
40. Shukla RS, Rao SK and Singh CB. Character association and path analysis in bread wheat under rainfed and partially irrigated condition. JNKVV Research Journal 2005;39:20-25.
41. Riaz-ud-Din Subhani GM, Naeem Ahmad, Makhdoom Hussain and Aziz-ur-Rehman; 2010.
42. Hama SJ, Omer B, Rshead, K. The simple correlation coefficient and path analysis of grain yield and its related components for some genotypes of wheat (*Triticum aestivum* L.) for two seasons in Iraqi Kurdistan. Journal of Medicinal Plants Studies. 2016;4(1):68-70.

43. Dhanda Pooja, Yadav SS, Beniwal NR, RS Anu. Correlation and path coefficient analysis of some quantitative traits in recombinant inbred lines of bread wheat. International Journal of Chemical Studies, 2018; 6(3):350-354.
44. Shrivastava MN and Sharman KK. Analysis of path coefficient in rice. Zeitsch Pflanzen. 1976;77:174-177.
45. Gupta D, Mittal RK, Kant A and Singh M. Association studies for agro-physiological and quality traits of triticale x bread wheat derivatives in relation to drought and cold stress. Journal of Environmental Biology 2007;28:265-269.
46. Bhushan B, Bharti S, Ojha A, Pandey M, Gourav SS, Tyagi BS, Singh G. Genetic variability, correlation coefficient and path analysis of some quantitative traits in bread wheat. J. Wheat Res., 2013;5(1): 21-26.
47. Bhutta WM, Akhtar J, Anwar-ul-Haq M and Ibrahim M. Cause and effect relations of yield components in spring wheat (*Triticum aestivum L.*) under normal conditions. caderno de pesquisa serie biologia 2005;17:7-12.

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