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Inheritance Studies in Segregating Population of Bread Wheat (*Triticum aestivum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author AS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors ND and HAA managed the analyses of the study. Author HAA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The experimental material of present study comprised of 127 treatments and 4 check varieties in augmented design conducted during *rabi* season (2022) in research field of Genetics and Plant Breeding, Lovely Professional University, Phagwara, India. Observations were recorded for days to 50% heading, days to maturity, plant height, number of productive tillers per plant, ear length, number of spikelets per ear, ear weight, number of grains per ear, test weight, biological yield per plant, harvest index, chlorophyll content and grain yield per plant. Analysis of variance disclosed that treatments and check varieties are highly significant for all the characters. Phenotypic coefficient of variation noted higher magnitude than genotypic coefficient of variation for all the traits. Heritability combined with genetic advance as percent of mean is noted high for grain yield per plant, biological yield per plant, number of productive tillers per plant, ear weight, harvest index, test weight, ear length, number of spikelets per ear, number of grains per ear and plant height. The

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correlation coefficient assessed positive and highly significant for biological yield per plant, number of productive tillers per plant, harvest index, ear weight, plant height, test weight and ear length. Grain yield per plant recorded positive significant association with biological yield per plant (0.7816), number of productive tillers per plant (0.7051), harvest index (0.527), ear weight (0.4076), plant height (0.3632), test weight (0.3222), and ear length (0.2439), whereas negatively significantly associated with days to 50% heading (-0.4019) and days to maturity (-0.4019). The findings from path analysis unveiled that the maximum direct effect was noted for biological yield per plant, harvest index, number of spikelets per ear, number of productive tillers per plant, ear weight, days to 50% heading, test weight and days to maturity. Out of thirteen traits, eight traits exhibited direct positive effect on grain yield such as biological yield per plant (0.8282), harvest index (0.6061), number of spikelets per ear (0.107), number of productive tillers per plant (0.0191), ear weight (0.0138), days to 50% heading (0.011), test weight (0.0088), and days to maturity (0.0001).

Keywords: PCV; GCV; correlation; association; heritability; path analysis.

1. INTRODUCTION

As the world's number one cereal, wheat (*Triticum aestivum* L.,2n=6x=42) is a self-pollinated, hexaploid species, belonging to the Poaceae family, is known as the "King of Cereals" because of its large acreage under cultivation, abundant annual output, and commanding position in the global market for food grains. It possesses a genome AABBDD. Originating from South West Asia (Turkey), wheat is one of the most widely grown crops. This is particular cereal thrives in cool climatic conditions and plays a significant role in ensuring nutritional and food security in India. The FAO estimates global wheat output at 775.4 mt for 2021-22, with India's share at 103.9 mt [1-2]. Countries including China, India, United States of America, Russia, France, Australia, Canada, Turkey, Pakistan, Argentina, United States, Italy and Iran are important producers of wheat. UP (Uttar Pradesh), Punjab, MP (Madhya Pradesh), Haryana, Rajasthan, Bihar, Gujarat, Maharashtra, West Bengal, and Uttarakhand are the Indian regions with the highest wheat production [3].

Knowledge of genetic characteristics such as correlation, genetic advance, and heritability is required to find traits that contribute to yield in order to enhance yield [4]. In the plant improvement initiative, estimations of heritability are being used as criteria for selection. It has become standard practice in attempting to

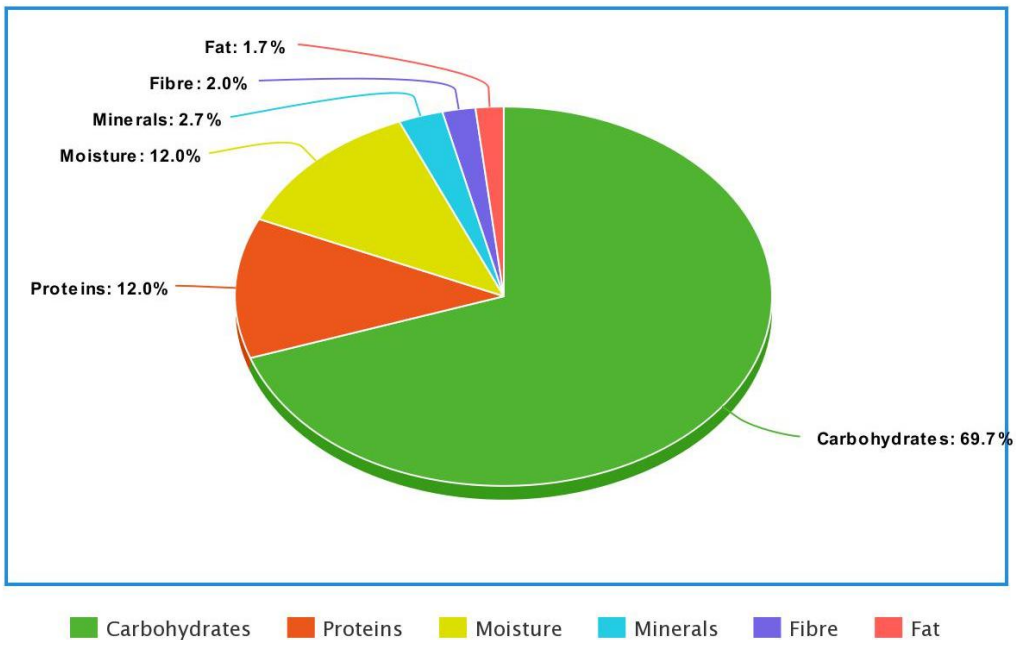

Fig. 1. Nutritional values of wheat grain

predict the extent to which a trait is inherited from parent to offspring [5]. Breeding programs rely heavily on correlation and path analysis. Correlation is used to determine the relationship between two or more traits. Path analysis study splits the correlation into direct and indirect effects among yield and yield contributing traits [6]. Selection is more likely to occur in populations with both high heritability and high genetic advance Johnson et al. [7]. The main objectives of this investigation are as follows:

1. To isolate superior segregants for grain yield and other traits.
2. To assess the genetic variability for yield and its related traits in segregating population of Bread Wheat.
3. To study nature and magnitude of association among yield traits through correlation and path analysis.

2. MATERIALS AND METHOD

The research was conducted during the *Rabi* season 2022 at the Research field of Genetics and Plant Breeding, Lovely Professional University, Phagwara, Punjab in augmented design. Sowing was done on 30th November 2022 with a spacing of 22.5 cm. The crossing was done in 2017 by our institution. Five observations are taken among 127 genotypes and 4 check varieties and selection is carried out on the basis of thirteen phenotypic traits such as days to 50% heading, days to maturity, plant height, number of productive tillers per plant, ear length, number of spikelets per plant, ear weight, number of grains per ear, 1000 grain weight, biological yield per plant, grain yield per plant, harvest index and chlorophyll content.

Chart 1. Name of frequent crosses

S.no	Treatment Name
1	RUJ 4037 x MP-3382
2	DBW-107 x MP-3382
3	HI-1544 x MP-3382

Chart 2. Check varieties

S.no	Check Name
1	GW-322
2	DDW-47
3	HI-8759
4	MP- 3336

2.1 Statistical Analysis

1. Analysis of variance [8]
2. Heritability and Genetic advance [9,7].
3. Correlation coefficient analysis [10]
4. Path coefficient analysis [11]

3. RESULTS AND DISCUSSION

Table 1 presents the results of the analysis of variance performed on thirteen traits, aiming to evaluate the significance of differences among the various treatments and checks. The study employed an augmented design, allowing for a comprehensive examination of the treatment's effects. This analysis provides valuable statistical insights into the variations observed among the treatments, aiding in the determination of their significance. It disclosed that treatments and check varieties are highly significant for all the traits such as days to 50% heading, days to maturity, plant height, number of productive tillers per plant, ear length, number of spikelets per ear, ear weight, number of grains per ear, test weight, biological yield per plant, harvest index, chlorophyll content and grain yield per plant. Corresponding observations are noted by [12-14].

Table 2 and Figure 2 revealed that for every trait, PCV was greater than GCV, suggesting that environmental factors in addition to genotype contributed to variation in character expression. These are further stated by [15-17]. The magnitude of PCV and GCV are (0-10%) low, (10-20%) moderate, and (above 20%) high. The high PCV and GCV for Grain yield per plant followed by biological yield per plant, number of productive tillers per plant, ear weight and harvest index. Comparable results were documented by Reena et al. [18].

Moderate PCV and GCV were recorded for test weight followed by ear length, plant height, number of spikelets per ear, number of grains per ear and chlorophyll content reported moderate PCV and low GCV. Equivalent results were registered by [16,19]. Low PCV and GCV are observed for days to flowering and days to maturity. Corresponding observations are noted by [20-21].

3.1 Heritability

Selection strategies and trait stability are heavily influenced by heritability. Table 2 and Fig. 3 displays broad sense heritability estimates for yield and associated characteristics. [4] categorized heritability as low (less than 40%), moderate (40-60%), and high (greater than 60%). All the traits obtained the highest

heritability except chlorophyll content such as Ear length (99.85), biological yield per plant (99.77), test weight(99.76), number of productive tillers per plant (99.47), ear weight (99.4), number of spikelets per ear (99.37), number of grains per ear (99.28), grain yield per plant (98.37), harvest index (96.45), plant height (85.25), days to 50% heading (67.54), and days to maturity (67.54). Moderate heritability was noted for chlorophyll content (47.79). These findings are consistent with those reported by [22-23] for Days to 50% heading, [17,24] for days to maturity, [24-26] for plant height, [24,27] for number of productive tillers per plant, [22,25] for number of spikelets per ear, [17-18] for ear weight [28] for number of grains per ear, [21,23,28] for test weight, [18, 27,28] for biological yield per plant, [22,28] for harvest index, [24,27] for chlorophyll index, [18,26,28].

3.2 Genetic Advance

Genetic advance as percent of mean in Table 2 and Fig. 3 is categorized as low (less than 10%), moderate (10-20%), and high (greater than 20%). The present study revealed high genetic advance as percent of mean for grain yield per plant (78.67), biological yield per plant (66.62), number of productive tillers per plant (66.62), ear weight (53.85), harvest index (48.13), test weight (35.41), ear length (29.17), number of spikelets per ear (23.67), number of grains per ear (23.62), and plant height (22.13). Moderated genetic advance as percent of mean noted for chlorophyll content (10.88) and remaining traits such as days to 50% heading (7.05) and days to maturity (5.2) registered low genetic advance as percent of mean. Equivalent results were registered by [2,16] for Days to 50% heading and days to maturity, [16,19] for plant height, [29-30] for number of productive tillers per plant, number of spikelets per ear, ear weight and number of grains per ear, test weight and biological yield per plant, harvest index, Chlorophyll index and grain yield per plant [16-28].

3.3 Correlation Coefficient

Correlation research showed that there is an association between yield and the variables that contribute to yield. Estimating genotypic correlation is important for determining the characteristic's true connection [31]. When two desired traits are positively correlated, the plant breeder can focus on improving both traits at once, however negative association will prevent the characters from expressing themselves similarly [16].

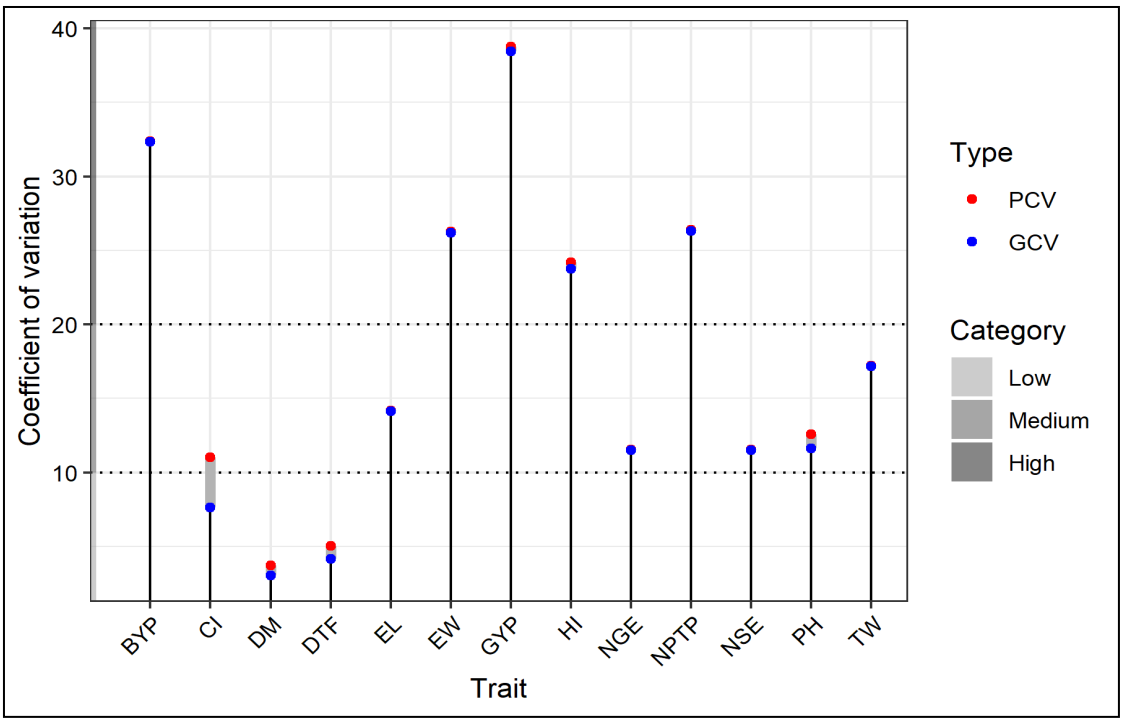

Fig. 2. GCV and PCV for 13 traits in F_5 generation in wheat

Table 1. Analysis of variance for various yield-contributing traits in wheat

S. No.	Source	Df	DTH	DM	PH	NPTP	EL	NSE	EW	NGE	TW	BYP	HI	CC	GYP
1	Treatment (ignoring Blocks)	130	26.16**	26.16**	116.5**	1.82**	1.85**	3.49**	0.39**	30.59**	41.7**	29.19**	103.02**	11.32**	5.98**
2	Treatment: Check	3	118.94**	118.94**	70.42**	0.6**	2.92**	5.82**	0.57**	70.37**	40**	25.06**	390.58**	0.79**	10.93**
3	Treatment: Test vs. Check	1	607.55**	607.55**	269.2**	36.08**	2.13**	48.71**	0.33**	309.41**	9.47**	2.81**	3031.72**	4.1**	89.74**
4	Treatment: Test	126	19.34**	19.34**	116.39**	1.58**	1.82**	3.08**	0.38**	27.43**	42**	29.5**	72.93**	11.62**	5.2**
5	Block (eliminating Treatments)	5	3.1^{ns}	3.1^{ns}	17.17^{ns}	0.01^{ns}	0.0028^{ns}	0.02^{ns}	0.0023^{ns}	0.2^{ns}	0.1^{ns}	0.07^{ns}	2.59^{ns}	3.94^{ns}	0.08^{ns}
6	Residuals	15	6.28	6.28	17.17	0.01	0.0028	0.02	0.0023	0.2	0.1	0.07	2.59	6.07	0.08
7	CV		2.86	2.11	4.8	1.99	0.55	0.91	2.02	0.96	0.84	1.54	4.78	7.95	5.19

DTH- Days to 50% heading, DM- Days to maturity, PH- Plant height, NPTP- Number of productive tillers per plant, EL- Ear length, NSE- Number of spikelets per ear, EW- Ear weight,

NGE- Number of grains per ear, TW- Test weight, BYP- Biological yield per plant, HI- Harvest index, CC- Chlorophyll content, GYP- Grain yield per plant.

**, ** significant at 5% and 1% level of significance*

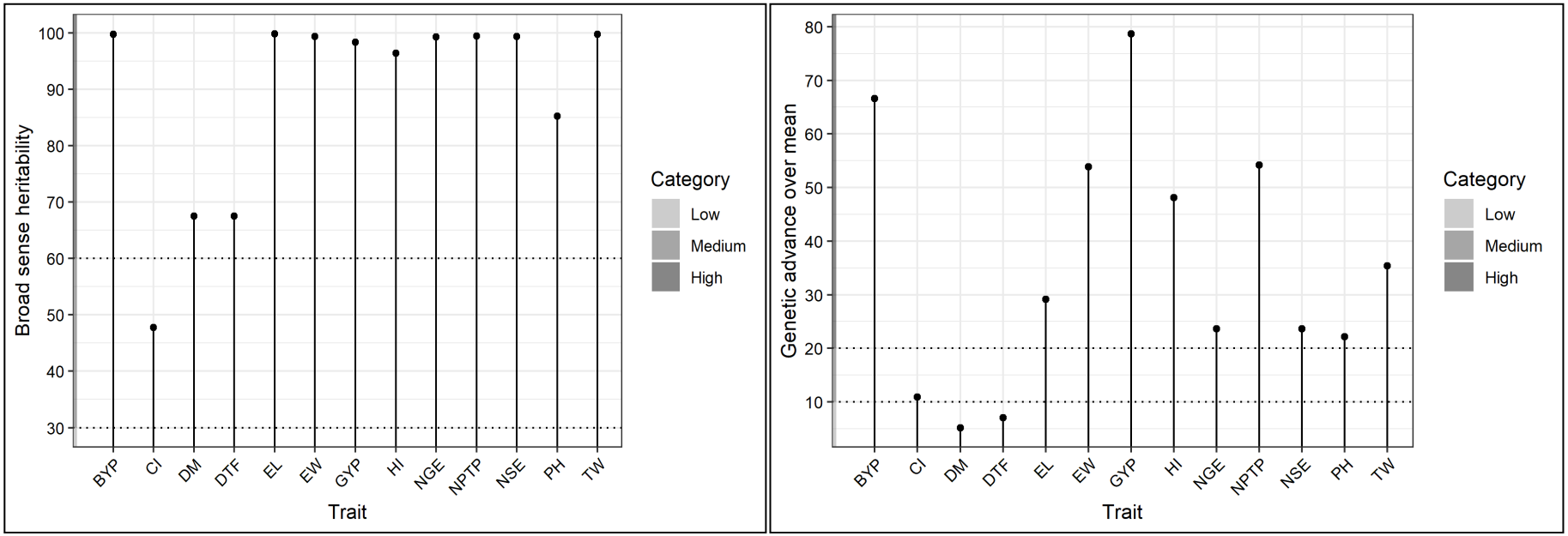

Fig. 3. Broad sense heritability and genetic advance over mean for 13 traits in F_5 generation in wheat

Table 2. Genetic variability parameters among thirteen characters

Traits	Mean	Range		GCV	PCV	hBS	GA	GAM
		Min	Max					
DTF	86.94	81.75	102.5	4.16	5.06	67.54	6.13	7.05
DM	117.94	112.75	133.5	3.06	3.73	67.54	6.13	5.2
PH	85.72	48.5	112.99	11.62	12.59	85.25	18.97	22.13
NPTP	4.76	2.62	8.96	26.33	26.4	99.47	2.58	54.18
EL	9.53	5.35	14.07	14.15	14.16	99.85	2.78	29.17
NSE	15.2	10.71	19.96	11.51	11.55	99.37	3.6	23.67
EW	2.36	1.3	4.32	26.18	26.26	99.4	1.27	53.85
NGE	45.42	32.14	59.81	11.49	11.53	99.28	10.73	23.62
TW	37.66	20	56	17.19	17.21	99.76	13.34	35.41
BYP	16.78	8.5	34.25	32.33	32.37	99.77	11.18	66.62
HI	35.3	11.29	57.74	23.76	24.19	96.45	16.99	48.13
CI	30.91	22.44	38.61	7.63	11.03	47.79	3.36	10.88
GYP	5.88	2.17	12.84	38.45	38.76	98.37	4.63	78.67

Table 3 reveals the association between thirteen yield and yield-attributing traits. Grain yield per plant recorded positive significant association with biological yield per plant (0.7816), number of productive tillers per plant (0.7051), harvest index (0.527), ear weight (0.4076), plant height (0.3632), test weight (0.3222), and ear length (0.2439), whereas negatively significantly associated with days to 50% heading (-0.4019) and days to maturity (-0.4019). Biological yield per plant is significantly positively correlated with number of productive tillers per plant (0.6854), ear weight (0.3859), plant height (0.2895), ear length (0.2633), number of grains per ear (0.2563), number of spikelets per ear (0.2437), and negatively correlated with days to 50% heading (-0.2633) and days to maturity (-0.2633). Test weight showed positive significant association with plant height (0.3579), harvest index (0.2528), ear weight (0.2341), and negative significant association with days to 50% heading (-0.4106), days to maturity (-0.4106), number of grains per ear (-0.2363), and number of spikelets per ear (-0.229). A significant positive genotypic correlation of harvest index was found for characters namely plant height (0.2268), number of productive tillers per plant (0.2103) and negative genotypic correlation for days to 50% heading (-0.3150), days to maturity (-0.3150) and number of spikelets per ear (-0.2449). Number of grains per ear shows positive association with number of spikelets per ear (0.9945), ear length (0.4349) and ear weight (0.2234), on other hand ear weight is positively associated with number of spikelets per ear (0.2229). Number of spikelets per ear and ear length are significantly positively associated with ear length (0.4099) and plant height (0.3933) respectively whereas plant height is negatively correlated with days to 50% heading (-0.3058) and days to maturity (-0.3058). Days to 50% heading is positive significant association with days to maturity (1.000). Comparable results were documented by [32-33] for days to 50% heading, days to maturity, plant height, number of productive tillers per plant, ear length, ear weight, number of grains per ear, harvest index, chlorophyll index, test weight and biological yield per plant [30-35].

3.4 Path analysis

Path analysis method indicates whether the link between the independent character and the dependent one, in this example, grain yield is the result of direct effect or the result of an indirect effect via another character. The direct effect of the independent variable demonstrates a genuine correlation between the two variables. The practice of selection can be employed to enhance the dependent variable in relation to a given character Sharma et al., 2018.

Table 4 disclosed that, out of thirteen traits, eight traits exhibited direct positive effect on grain yield such as biological yield per plant (0.8282), harvest index (0.6061), number of spikelets per ear (0.107), number of productive tillers per plant (0.0191), ear weight (0.0138), days to 50% heading (0.011), test weight (0.0088), and days to maturity (0.0001). Four traits exhibited direct negative effect on grain yield such as number of grains per ear (-0.0996), ear length (-0.0387), chlorophyll content (-0.0099), and plant height (-0.0004).

Table 3. Understanding the Correlation patterns among yield and yield attributing traits

	DTF	DM	PH	NPTP	EL	NSE	EW	NGE	HI	CI	TW	BYP	GYP
DTF	**1**	1.000**	-0.3058**	-0.2042	-0.17	0.1207	-0.1757	0.1181	-0.3150**	0.1864	-0.4106**	-0.2633**	-0.4019**
DM		**1**	-0.3058**	-0.2042	-0.17	0.1207	-0.1757	0.1181	-0.3150**	0.1864	-0.4106**	-0.2633**	-0.4019**
PH			**1**	0.0982	0.3933**	-0.004	0.1744	0.0177	0.2268*	0.0189	0.3579**	0.2895**	0.3632**
NPTP				**1**	0.146	0.0777	0.1401	0.1053	0.2103*	-0.0262	-0.126	0.6854**	0.7051**
EL					**1**	0.4099**	0.176	0.4349**	0.1011	0.0315	-0.0174	0.2633**	0.2439*
NSE						**1**	0.2229*	0.9945**	-0.2449*	-0.0273	-0.229*	0.2437*	0.0496
EW							**1**	0.2234*	0.1258	-0.0512	0.2341*	0.3859**	0.4076**
NGE								**1**	-0.2095	-0.0125	-0.2363*	0.2563**	0.0797
HI									**1**	-0.026	0.2528**	-0.09	0.527**
CI										**1**	-0.0634	-0.0524	-0.0717
TW											**1**	0.1977	0.3222**
BYP												**1**	0.7816**

**, ** significant at 5% and 1% level of significance*

Table 4. Direct and Indirect effects of different characters on Grain yield

	DTF	DM	PH	NPTP	EL	NSE	EW	NGE	HI	CI	TW	BYP	GYP
DTF	**0.011**	0.011	-0.0034	-0.0022	-0.0019	0.0013	-0.0019	0.0013	-0.0035	0.002	-0.0045	-0.0029	-0.4019
DM	0.0000	**0.0001**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.4019
PH	0.0001	0.0001	**-0.0004**	0.0000	-0.0002	0.0000	-0.0001	0.0000	-0.0001	0.0000	-0.0002	-0.0001	0.3632
NPTP	-0.0039	-0.0039	0.0019	**0.0191**	0.0028	0.0015	0.0027	0.002	0.004	-0.0005	-0.0024	0.0131	0.7051
EL	0.0066	0.0066	-0.0152	-0.0056	**-0.0387**	-0.0158	-0.0068	-0.0168	-0.0039	-0.0012	0.0007	-0.0102	0.2439
NSE	0.0129	0.0129	-0.0004	0.0083	0.0439	**0.107**	0.0239	0.1064	-0.0262	-0.0029	-0.0245	0.0261	0.0496
EW	-0.0024	-0.0024	0.0024	0.0019	0.0024	0.0031	**0.0138**	0.0031	0.0017	-0.0007	0.0032	0.0053	0.4076
NGE	-0.0118	-0.0118	-0.0018	-0.0105	-0.0433	-0.0991	-0.0223	**-0.0996**	0.0209	0.0012	0.0235	-0.0255	0.0797
HI	-0.191	-0.191	0.1375	0.1274	0.0613	-0.1484	0.0762	-0.127	**0.6061**	-0.0158	0.1532	-0.0545	0.527
CI	-0.0018	-0.0018	-0.0002	0.0003	-0.0003	0.0003	0.0005	0.0001	0.0003	**-0.0099**	0.0006	0.0005	-0.0717
TW	-0.0036	-0.0036	0.0032	-0.0011	-0.0002	-0.002	0.0021	-0.0021	0.0022	-0.0006	**0.0088**	0.0017	0.3222
BYP	-0.218	-0.218	0.2397	0.5676	0.218	0.2018	0.3196	0.2123	-0.0745	-0.0434	0.1637	**0.8282**	0.7816

Biological yield per plant showed high positive direct effect and had significant association with grain yield (0.7816), it has a maximum positive indirect effect via number of productive tillers per plant (0.5676), ear weight (0.3196), plant height (0.2397) and number of grains per ear (0.2123). Direct effect of harvest index on grain yield was positive, and its indirect positive contribution via test weight (0.1532), plant height (0.1375), and number of productive tillers per plant (0.1375).

Ear length and number of grains per ear showed negative direct effect on grain yield although the magnitudes are very small. Chlorophyll content noted direct negative effect and negative indirect contribution via days to maturity (-0.0018), days to 50% heading (-0.0018), ear length (-0.0003), and plant height (-0.0002), meanwhile indirect positive contribution via test weight (0.0006), biological yield per plant (0.0005), ear weight (0.0005), harvest index (0.0003), number of spikelets per ear (0.0003) and number of grains per ear (0.0001).

Direct effect of number of spikelets per ear on grain yield is positive and have less magnitude of association with grain yield (0.0496) and however its positive indirect effect via number of grains per ear (0.1064), ear length (0.0439), biological yield per plant (0.0261), ear weight (0.0239), days to 50% heading (0.0129), days to maturity (0.0129) and number of productive tillers per plant (0.0083). Number of productive tillers per plant noted positive direct effect on grain yield and had a significant association with grain yield (0.7051), however, it has maximum positive indirect effect via biological yield per plant (0.0131), ear length (0.0028), ear weight (0.0027), plant height (0.0019), number of spikelets per ear (0.0015), harvest index (0.004) and number of grains per ear (0.004). Similar findings were documented by [29-37].

4. CONCLUSION

The High heritability in combination with high genetic advance is noted for characters such as grain yield per plant, biological yield per plant, number of productive tillers per plant, ear weight, harvest index, test weight, ear length, number of spikelets per ear, number of grains per ear and plant height, it would be more efficacious for the desired genetic enhancement to specify that these characters are subjected to additive gene effects and direct selection for said traits. Grain yield per plant recorded positive significant association with biological yield per plant, number of productive tillers per plant, harvest index, ear weight, plant height, test weight, and ear length, hence, the selection process for these traits can be directly correlated with enhancement of grain yield in wheat. Path analysis disclosed that, eight traits exhibited direct positive effect on grain yield such as biological yield per plant, harvest index, number of spikelets per ear, number of productive tillers per plant, ear weight, days to 50% heading, test weight, and days to maturity whereas four traits exhibited direct negative effect on grain yield such as number of grains per ear, ear length, chlorophyll content, and plant height. It is imperative to prioritise each character when selecting superior types.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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