The Pharma Innovation Journal 2021; 10(8): 482-488

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(8): 482-488

www.thepharmajournal.com
Received: 19-06-2021
Accepted: 24-07-2021

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Correlation and path coefficient analysis for yield and yield attributing traits in advanced bread wheat (*Triticum aestivum* L.) Lines

Aman Singh, Juhi Pandey, Sudhanshu Singh, Ravi Pratap Singh and RK Singh

Abstract
Knowledge of nature and magnitude of genetic variability among genotypes, mutual association between yield and attributing traits is important for effective selection in plant-breeding program. Ninety advanced bread wheat lines along with four standard checks *viz.* HD-2967, NW-5054, DBW-187 and HD–2733 were evaluated at Main experimental station of Acharya Narendra Dev University of Agriculture and Technology, Ayodhya (U.P.) in augmented block design in Rabi 2020 to evaluate the correlation of yield and yield attributing traits and determine the direct and indirect effects of yield attributing traits on grain yield. Analysis of variance showed significant differences among the tested genotypes for all the majority of agro-morphological characters under study which clearly indicates high variability among the tested advanced bread wheat lines. Grain yield had highly significant and positive correlation with biological yield per plant, harvest index (%), days to maturity, days to 50% flowering, plant height and tillers/plant. Maximum positive direct effect on grain yield per hectare was exerted by biological yield per plant followed harvest index, days to 50% flowering and plant height. Selection based on these traits could be more effective to maximize grain yield. Path analysis showed that maximum positive direct effect on grain yield per hectare was exerted by biological yield per plant followed harvest index, days to 50% flowering and plant height. This implies the true relationship between these traits and grain yield. Consequently, these traits should be considered as important selection criteria in future breeding program for the development high yielding wheat varieties.

Keywords: Triticum, bread wheat; correlation; path coefficient; yield attributing traits

Introduction

Wheat (spp. L.) is an annual plant belongs to the family Poaceae, tribe Triticeae and subtribe Triticineae. Wheat is extensively grown in temperate regions of the world and occupies almost 17% of total crop acreage. It is the staple food for the more than 40% of the world's population (Mohammadi-joo *et al.*, 2015) [23]. It has been described as the 'King of cereals' due high crop acreage, high productivity and the prominent position it occupies in the world food grain trade. It also provides 21% of the total food calories and 20% of the protein for more than 4.5 billion wheat consuming population of 94 developing countries and contributing more than 30% of food basket of the country. The starchy endosperm of mature wheat grain consists of carbohydrates (55-75%) and storage proteins (10–20%) (Gillies *et al.*, 2012) [16]. The aleurone layer of the wheat grain is most important source of vitamins, micronutrients, minerals, phytochemicals and fiber in wheat grain, although it is also rich in proteins and lipids (Geisler-Lee and Gallie, 2005; Regvar *et al.*, 2011) [15, 25]. Wheat is known for its remarkable adoption to a wide range of environments and its role in world economy. The crop being cultivated as winter and spring in the world, winter wheat is grown in cold countries like Europe, the USA, Australia, Russian Federation, etc., while spring wheat is grown in Asia and in some parts of the USA. India, being blessed and enriched with a diverse agro ecological condition, ensuring food and nutrition security to a majority of the Indian population through production and steady supply particularly in the recent past, is the second largest producer of wheat worldwide. In India during 2019-20 rabi season wheat has been cultivated in 30.55 million hectares contributing 24.94% of total crop acreage. India wheat production 2019-20 has made and another landmark achievement by producing 107.18mt with an average national productivity of 3508kg/ha. During the past year production was also more than 100 mt (103.7mt) and the current year production has witnessed a change of 3.58mt (+3.46%).

It is agronomically and nutritionally most important cereal essential for food security, poverty alleviation and improved livelihoods. As per an estimate to feed the growing population, the country wheat requirement by 2030 has been estimated at 100 million metric tons. To achieve this target, the wheat production has to be increased at the rate of < 1m. mt per annum (Sharma *et al.*, 2011) and this can be achieved by enhancing area under wheat cultivation and by developing improved wheat varieties through heterosis breeding among parents having high genetic divergent. It is important that variability for economic traits must exist in the working germplasm for profitable exploitation following recombination breeding and selection. Selection is usually practicing for pooling favorable genes while the hybridization is predominantly utilized to accumulate favorable genes in variety for obtaining desired improvement. The presence of genetic diversity and genetic relationship among genotypes is a prerequisite and paramount important for successful wheat breeding programme. Knowledge on the nature and magnitude of the genetic variation governing the inheritance of quantitative characters like yield and its components is essential for effective genetic improvement. Precise information on the nature and degree of genetic diversity helps the plant breeder in choosing the diverse parents for purposeful hybridization (Samsuddin, 1985) [28]. Several genetic diversity studies have been conducted on different crop species based on quantitative and qualitative traits in order to select genetically distant parents for hybridization (Shekhawat *et al.*, 2001) [31].

In view of the above observation present study was initiated using advanced breeding lines to assess the relationship between yield and yield attributing traits and to determine the direct and indirect effects of different yield attributing traits on grain yield of bread wheat.

Materials and Methods

Description of the experimental site

Experiment was conducted at Main experimental station of Acharya Narendra Dev University of Agriculture and Technology, Ayodhya (U.P.) in Rabi season 2020-21. Experimental plot was well leveled having proper drainage. Experimental site lies between the geographical coordinates 24.470 and 26.560 N latitude and 82.120 and 83.980 E longitude at an altitude of 113 m above from sea level in the Gangetic Alluvial Plains of Eastern Uttar Pradesh. The soil of the experimental site is silty loam in texture having low organic carbon content (0.38%) with pH 7.4. Climate of the experimental site is sub-humid sub-tropical with hot summers and fairly cool winters. The average annual rainfall is about area 1040 mm.

Experimental materials and design

The experimental material was consists of 90 bread wheat advanced lines including four standard check varieties *viz.* HD-2967, NW-5054, DBW-187 and HD–2733. Accessions were grown in augmented block design with two rows of 2.5 meter row length during Rabi 2020. Spacing of 30 and 10 centimeter between rows and plants respectively was maintained. Recommended package of practices and plant protection measures were adapted for proper crop growth. Five randomly selected plants per line per replication were used for recording the observations days to 50% flowering, plant height, flag leaf area, tillers plant^{-1}, spike length, peduncle length, days to maturity, 1000 grain wt., biological yield plant^{-1}, grain yield plant^{-1} and harvest Index (%). The collected data were subjected to analysis of variance (ANOVA) as per the method suggested by the Federer (1956) [13]. Correlation between studied traits was computed using formula suggested by Searle (1961) [29]. Direct and indirect effects of yield attributing traits up on grain yield were measured by path analysis as described by Dewey & Lu (1959) [10].

Results and Discussion

Analysis of variance

Mean squares of characters under study from ANOVA for the tested materials were presented in Tables - 1. The result presented in the table -1 revealed that there were highly significant differences ($P< 0.05$ and $P< 0.01$) among the genotypes for all the studied agro-morphological traits, indicating the existence of sufficient genetic variability among bread wheat genotypes It was also reflected by the broad ranges for each trait as presented in (Table- 2). The genetic diversity among genotypes will be helpful in selection procedures of further bread wheat breeding programme. Similar results were reported by Awale *et al.*, 2013 [7]; Kumar *et al.*, 2014; Zeeshan *et al.*, 2014 [19]; Adhiena *et al.*, 2016 [35] and Arya *et al.* (2017) [4] in their previous studies on bread wheat.

Correlation between yield and yield attributing traits

Simple correlation coefficients were estimated for all the characters studied with grain yield per plant and presented in table-3. The grain yield per plant exhibited highly significant and positive correlation with biological yield per plant (0.978), harvest index (%) (0.959), days to maturity (0.963), days to 50% flowering (0.954), plant height (0.935) and tillers/plant (0.849). The significant correlation suggests that these traits could be used as indirect selection traits for grain yield, i.e., increase of these traits would increase grain yield per plant. The study of correlation among yield and yield contributing traits also suggests that plant height, number of productive tillers per plant, 1000 grain weight, harvest index and biological yield were the most important characters which possessed highly positive correlation with grain yield per plant. Therefore, these characters could be utilized in further breeding program for development of high yielding wheat varieties.

Correlation among yield attributing traits

Days to 50% flowering had highly significant positive correlation with days to maturity, harvest index (%) and biological yield per plant at phenotypic level. This implied that increasing days to 50% flowering would increase days to maturity, harvest index (%) and biological yield per plant.

Days to maturity positive significant correlated with biological yield per plant, harvest index (%) and tillers per plant which indicates that increase in the gap between heading date and maturity date leads to increase in biological yield per plant, tillers per plant, and harvest index. Mohammad *et al.* (2005) [22] also reported that days to maturity had significant positive genotypic correlation with grain-filling period, plant height, number of spikelets spike^{-1}, and thousand seed weight. Plant height exhibited positive significant association with biological yield per plant, spike length, thousand seed weight, biological yield and harvest index which implies that increase in plant height leads to increase in spike length, thousand seed weight, biological yield and harvest index.

Number of productive tillers per plant displayed positive and significant relationship with the spike length, Biological yield per plant, 1000- grain weight and harvest index suggesting that increase in tiller number adds the value of those traits. It was also indicated that number of tillers per plant may be an effective trait to select higher yielding genotypes. Positive and significant correlation between spike length, thousand seed weight and harvest index was also observed.

Correlation between days to 50% flowering and peduncle length was non-significant and positive. Strong association of peduncle length with other yield attributing traits may be useful in indirect selection for yield improvement. Short stature and high yielding varieties can be developed by controlling the favourable genes for peduncle length. All yield related traits except peduncle length, spike length, and flag leaf area were controlled by dominant genes. Selection in the later generations for peduncle length may indirectly improve yield.

The interrelation between yield contributing characters exhibits that thousand seed weight was positively correlated with harvest index, Biological yield per plant and flag leaf area which indicated high portion of photosynthesis was due to increase thousand seed weight. This result is in agreement with the finding of earlier workers *viz*. Kalimullah *et al.*, 2012 [18]; Laei *et al.*, 2012 [20]; Zafarnaderi *et al.*, 2013 [34], Ayer *et al.*, 2017 [8] and Baye *et al*., 2020 [5].

Path coefficient analysis

The result of path coefficient analysis of the present study was presented in Tables 4. Maximum positive direct effect on grain yield per hectare was exerted by biological yield per plant followed harvest index (0.838), days to 50% flowering (0.629), plant height (0.405) and Flag leaf area (0.124). The high magnitude direct effects of these characters on grain yield could be considered as causes of such high correlation. This means that a slight increase in one of these traits may directly contribute to grain yield. Sabit *et al.* (2017) [27] and Baye *et al.*, have been reported that plant height, days to flowering, biological yield, and harvest index had positive direct effect on grain yield per plant at genotypic level in bread wheat which is similar with the present study. Chowdhry *et al.* (1991) [9], also reported positive and direct effect of harvest index (0.443) and biological yield (0.327) on grain yield per plant. Negative direct effect was exhibited by remaining yield attributing traits *viz*. Peduncle legth (-0.301), days to maturity (-1.272), spike length (-0.216), 1000- grain weight (-0.206) and number of productive tillers per plant (-0.227). Since the direct effect were negative, so the direct selection for these traits to improve yield will be undesirable.

The highest positive indirect effect on grain yield was exhibited by biological yield per plant (1.143) via test weight, harvest index (0.829) via days to 50% flowering, plant height (0.391) via days to maturity, days to 50% flowering (0.623) via days to maturity and flag leaf area (0.116) via plant height. Remaining studied yield attributing traits exerted negative indirect effect on grain yield per plant.

On the basis of path coefficients analysis, it was also suggested that biological yield followed by harvest index and days to 50% flowering are the main contributors to grain yield in the present investigation. The finding of Leilah and Al-Khateeb (2005) [21], Abinasa *et al.* (2011) [3], Dutamo *et al.* (2015) [11] and Obsa *et al.* (2017) [24] also showed that harvest index and biomass yield was exerted the highest positive direct effect on grain yield, it is in confirmation of the present study. This implies that selection based on these traits may be effective to improve grain yield of bread wheat. Singh and Choudhury (1985) [32] suggested that if the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, the correlation explains the true relationship and the direct selection based on these traits is effective. The result of the present study was also in agreement with the findings of Arega *et al.* (2007) [14], Singh *et al.* 2010 [33], Potdukhe *et al.* 2013, Gelalcha and Hanchinal (2013) [26], Baye *et al.*, (2020) [5], reported that traits such as biomass and harvest index, which showed highly significant correlation with grain yield, can be used as selection indices in grain yield improvement. Therefore, selection for characters will possibly improve other component characters thereby improving grain yield.

The residual effect in path analysis determines how best the resultant component (independent) variables account for the variability of the causal (dependent variable), grain yield per plant (Singh and Chaudhary, 1985) [32]. Residual effect in the present study was computed 0.07295 showing that 92.70% of the variability in grain yield was explained by the component factors. It was in the confirmation with the findings of Gelalcha and Hanchinal (2013) [26] and Arega *et al.* (2007) [14], who reported residual effects 0.065 and 0.0083, respectively, indicating that characters included in the study explained high percentage of variation in grain yield per plot. It also indicates that in addition to the studied characters, there are also other factors to justify grain yield per plant changes (El-Mohsen *et al.*, 2012) [6].

Knowledge of nature and magnitude of variation in the available breeding materials, interrelation between yield and attributing traits is perquisite for the successful breeding programme. Grain yield per plant had highly significant and positive correlation with biological yield per plant, harvest index (%), days to maturity, days to 50% flowering, plant height and tillers/plant. Maximum positive direct effect on grain yield per hectare was exerted by biological yield per plant followed harvest index, days to 50% flowering and plant height. It indicates the true relationship between these traits and grain yield. Consequently, these traits should be considered as important selection criteria in future breeding program for the development high yielding wheat varieties.

The highest positive indirect effect on grain yield was exhibited by biological yield per plant via test weight, harvest index via days to 50% flowering, plant height via days to maturity, days to 50% flowering via days to maturity and flag leaf area via plant height. On the basis of path analysis it was concluded that biological yield followed by harvest index and days to 50% flowering are the main contributors to grain yield. Therefore, selection based on high biological yield and harvest index together with the above indicated traits is recommended for further bread wheat breeding programme for the development of high yielding varieties/lines.

Table 1: Analysis of Variance in Augmented Design for 11 agro-morphological characters in wheat genotypes

	DF	Days to 50% flowering	Penduncle length(cm)	Plant height (cm)	Days to maturity	Tillers /plant	Spike length (cm)	Flag leaf area (cm)	Biological Yield/plant (g)	Test weight (g)	Harvest index (%)	Grain yield/ plant
Block (ignoring Treatments)	5	8.751**	18.174***	27.781***	55.579***	1.32***	18.379	73.394***	26.155***	11.519***	5.949**	2.591***
Treatment (eliminating Blocks)	93	9.228***	4.764***	59.107***	11.677*	0.697***	2.427	8.72***	13.154***	8.471***	2.95 *	1.397***
Checks	3	106.333***	11.86***	29.73***	71.819***	1.139***	12.244	3.41	23.405***	3.699**	32.097***	5.688***
Checks+Var vs. Var.	90	5.991 **	4.528***	60.087***	9.672	0.682***	2.1	8.897***	12.813***	8.63***	1.979	1.254**
ERROR	15	1.466	0.202	0.724	5.253	0.05	4.664	1.399	0.39	0.653	1.257	0.292
Block (eliminating Check+Var.)	5	1.001	0.883*	0.666	13.874	0.059	6.015	11.236***	1.623 *	0.717***	3.321	0.981*
Entries (ignoring Blocks)	93	9.645 ***	5.694***	60.565***	13.919*	0.765***	3.092	12.061 ***	14.473***	9.052	3.092*	1.484***
Checks	3	106.333***	11.86***	29.73 ***	71.819***	1.139***	12.244	3.41	23.405***	3.699**	32.097***	5.688***
Varieties	89	6.452 **	5.46***	33.087***	11.538*	0.538***	2.566	12.027***	12.51***	7.419***	2.122	1.14**
Checks vs. Varieties	1	3.743	8.074***	2598.64***	52.107 **	19.777***	22.42*	41.083 ***	162.445***	170.432***	2.34	19.467***
ERROR	15	1.466	0.202	0.724	5.253	0.05	4.664	1.399	0.39	0.653	1.257	0.292
Ci - Cj	1	1.490	0.553	1.047	2.82	0.275	2.658	1.456	0.768	0.994	1.38	0.664
BiVi - BiVj	1	3.650	1.355	2.565	6.909	0.675	6.51	3.566	1.882	2.436	3.38	1.627
BiVi - BjVj	1	4.081	1.515	2.867	7.724	0.754	7.279	3.986	2.104	2.723	3.779	1.82
Ci - VI	1	3.117	1.157	2.190	5.899	0.576	5.559	3.045	1.607	2.08	2.886	1.39

Table 2: Mean, Range and Coefficient of variation (CV) for 11 characters among wheat genotypes

Genotypes	Days to 50% flowering	Peduncle length(cm)	Plant height (cm)	Days to maturity	Tillers /plant	Spike length (cm)	Flag leaf area (cm)	Biological Yield/plant (g)	Test weight (g)	Harvest index (%)	Grain yield/plant (g)
PBW-756	79.25	18.13	95.35	124.88	6.33	9.07	21.32	32.60	38.46	38.09	12.42
DBW-220	81.25	18.13	88.55	122.88	6.93	9.27	18.72	34.20	37.86	38.59	13.22
DBW-150	78.25	18.93	100.75	124.88	7.33	10.07	19.32	32.40	39.66	36.39	11.82
HTW-6	79.25	19.53	87.15	121.88	6.43	10.47	18.12	34.40	39.26	38.99	13.42
WH-730	78.25	20.33	82.75	125.88	7.33	9.67	19.32	36.50	34.46	35.69	13.02
WH-127	82.25	22.53	90.15	133.88	6.33	8.87	21.52	35.80	40.26	37.99	13.62
BRB-3723	80.25	23.53	83.55	122.88	6.93	11.87	20.72	36.00	37.66	38.89	14.02
DBW-39	82.25	22.33	89.15	123.88	7.33	12.67	21.52	31.40	33.06	39.49	12.42
16th HTWYT 50	78.25	22.13	101.15	127.88	5.33	13.67	19.32	39.00	39.26	37.49	14.62
25th SAWYT 308	80.25	24.93	94.15	129.88	5.73	12.27	17.32	42.40	37.86	36.69	15.52
25th SAWYT 325	80.25	22.13	99.95	127.88	7.53	12.27	23.52	37.60	36.66	38.39	14.42
25th SAWYT 336	84.25	27.53	91.75	125.88	6.93	10.27	19.32	39.40	41.66	38.19	15.02
25th SAWYT 347	84.25	18.33	80.15	123.88	6.93	12.07	19.52	32.20	42.06	38.49	12.42
35th SAWAN 3103	83.25	18.93	90.15	125.88	7.33	10.47	19.12	35.40	41.26	38.49	13.62
GRU-2010-18/7	80.25	20.53	90.15	122.88	6.53	12.27	19.32	34.20	38.46	39.79	13.62
DWAP-15031	76.00	20.88	86.85	123.63	7.13	12.97	16.22	41.17	40.01	35.86	14.80
HS-627	78.00	25.08	95.25	126.63	6.73	11.77	15.22	34.77	37.61	38.76	12.80
38th ESWYT 104	83.00	22.68	83.45	128.63	6.13	12.17	18.02	33.27	40.01	35.06	11.60
38th ESWYT 129	80.00	21.88	81.05	124.63	6.73	9.57	15.82	35.27	37.01	36.46	12.80
38th ESWYT 148	85.00	24.48	90.45	123.63	7.13	11.37	17.22	31.67	38.21	37.56	11.80
50th IBWSN 1095	82.00	22.88	82.25	122.63	5.73	12.17	16.02	44.47	41.61	35.36	15.80
50th IBWSN 1283	85.00	22.48	81.45	125.63	5.53	11.57	17.42	35.07	34.81	36.56	12.80
16th HTWYT 22	80.00	25.48	109.85	128.63	6.83	12.97	17.82	38.07	37.61	39.36	15.00
16th HTWYT 41	79.00	24.88	93.05	122.63	6.33	11.97	16.42	35.37	40.61	36.26	12.80
DBW-93	80.00	25.48	89.45	122.63	6.83	12.37	19.82	34.07	36.81	37.76	12.80
DBW-129	83.00	20.68	90.05	124.63	7.13	13.37	20.02	34.47	36.01	37.36	12.80
HI-8751	78.00	24.88	82.25	126.63	5.53	12.57	24.82	30.87	40.61	37.96	11.60
MP-1338	83.00	25.48	85.95	125.63	5.53	11.37	23.22	36.07	41.41	38.36	13.80
HIKK-09	84.00	22.88	90.05	125.63	7.13	9.97	25.02	36.67	39.61	37.66	13.80
KBRL-82-2	80.00	21.68	107.45	126.63	6.73	13.17	23.22	32.27	34.01	37.46	12.00
DDK-1051	78.25	24.43	88.25	129.38	5.28	10.12	26.35	41.10	40.86	36.81	15.15
ELW-16	80.25	21.23	84.45	125.38	7.48	11.92	26.35	31.80	41.66	38.91	12.35

HS-626	80.25	21.23	93.25	124.38	5.28	9.12	20.35	38.20	36.06	36.01	13.75
TL-3007	78.25	24.43	95.05	123.38	6.08	10.52	22.75	30.10	42.66	39.11	11.75
HS-644	79.25	21.23	98.15	125.38	5.68	9.72	23.95	35.60	38.06	35.91	12.75
WH-1232	79.25	25.43	85.85	124.38	6.48	10.92	27.15	35.20	37.26	36.91	12.95
HI-8759	79.25	21.23	87.85	125.38	7.08	10.52	19.75	39.20	32.66	34.11	13.35
K-1317	78.25	22.43	85.85	124.38	6.68	11.92	18.15	34.00	34.06	38.21	12.95
DWAP-1530	79.25	25.03	89.85	126.38	5.08	8.92	18.95	30.10	41.86	39.11	11.75
UASD-DT-6	83.25	23.83	84.15	127.38	6.68	10.12	19.95	37.50	35.06	37.21	13.95
MP-3382	84.25	24.43	94.45	123.38	7.28	11.12	18.35	31.90	37.06	38.21	12.15
DBW-246	80.25	22.23	96.05	122.38	7.48	12.72	20.95	37.10	34.06	37.61	13.95
UAS-334	79.25	24.43	102.25	124.38	6.28	9.92	18.75	30.50	37.06	39.11	11.85
K-1006	75.25	22.23	88.85	123.38	5.48	12.12	21.15	34.20	36.06	37.91	12.95
AKAW-4927	84.25	22.23	85.45	129.38	7.28	10.32	20.35	30.00	35.26	39.21	11.75
FLW-10	83.25	24.18	91.15	132.63	7.28	14.47	17.72	35.70	33.26	38.09	13.60
HIKK-06	84.25	24.58	96.35	134.63	6.68	13.67	16.72	37.30	36.26	36.99	13.80
HD-1609	81.25	22.38	92.55	130.63	6.88	14.47	17.32	38.70	34.26	38.69	15.00
TL-3066	78.25	21.38	86.35	125.63	6.28	10.67	20.32	36.70	42.06	36.99	13.60
HIKK-05	79.25	19.18	81.15	124.63	6.48	10.27	20.52	33.30	38.46	38.39	12.80
HD-3043	78.25	20.18	87.35	127.63	6.88	11.07	19.32	35.20	34.46	38.59	13.60
HUW-699	81.25	20.58	92.35	128.63	6.88	13.67	22.72	32.90	34.46	37.69	12.40
MACS-3349	81.25	20.98	85.35	129.63	6.48	14.47	22.32	38.70	35.26	38.69	15.00
BRW-2723	80.25	21.78	90.55	127.63	6.68	12.47	23.72	33.70	38.26	36.69	12.40
HI-1612	83.25	21.58	83.15	129.63	6.68	9.67	22.72	29.70	41.66	40.39	12.00
WH-1080	79.25	21.38	91.35	127.63	5.88	9.87	21.72	32.70	36.06	39.09	12.80
UAS-57	81.25	23.78	84.15	130.63	6.68	11.07	16.52	38.10	35.26	38.29	14.60
DBW-107	79.25	18.58	87.55	127.63	7.28	11.27	22.62	31.50	38.06	39.39	12.40
GJW-463	79.25	18.78	83.15	126.63	6.48	11.27	26.52	36.70	39.26	38.69	14.20
KRL-283	84.25	19.58	86.75	130.63	5.88	9.47	18.52	33.30	34.46	40.19	13.40
DM-6	82.25	22.88	83.20	124.88	6.93	12.60	23.17	35.15	37.99	39.66	13.95
DM-7	76.25	24.08	86.40	125.88	7.33	11.20	23.37	31.75	36.39	40.66	12.95
DWAP-1108	75.25	26.28	89.20	129.88	6.93	12.00	24.57	29.55	39.59	40.86	12.15
FLW-22	81.25	26.28	99.00	134.88	6.73	10.60	25.57	40.05	38.39	38.36	15.35
TLW-10	76.25	20.88	96.20	125.88	7.33	9.20	30.37	31.65	35.39	40.06	12.75
CG-1013	81.25	22.68	87.40	131.88	6.73	10.20	31.77	35.65	34.59	39.66	14.15
WH-1127	80.25	22.48	85.40	138.88	6.33	8.20	31.77	31.45	39.59	41.06	12.95
WAPD-1508	84.25	20.88	92.00	133.88	6.93	9.80	30.57	31.05	35.39	40.86	12.75
WAPD-1516	79.25	23.68	90.00	128.88	6.93	11.80	29.37	29.35	35.99	41.16	12.15
WAPD-1519	78.25	23.48	89.60	127.88	6.73	9.00	26.57	36.75	39.39	38.96	14.35
WAPD-1524	79.25	26.68	91.00	129.88	6.53	12.20	27.37	32.25	41.29	40.66	13.15
DBW 221	75.25	26.28	95.00	124.88	5.73	13.60	25.57	30.15	40.79	40.66	12.35
HI 8713	84.25	23.88	88.10	133.88	6.53	12.80	23.37	35.15	37.99	40.16	14.15
DWAP-1531	81.25	22.88	91.20	132.88	7.33	11.60	24.57	34.55	36.19	40.26	13.95
GW-499	80.25	26.08	87.00	129.88	6.93	11.80	24.77	40.05	39.59	37.86	15.15
RAJ-4079	78.00	25.53	87.20	126.63	5.68	13.20	24.42	37.40	38.81	37.69	14.10
RAJ-1238	77.00	23.93	85.20	123.63	6.48	10.80	23.42	38.60	35.41	38.09	14.70
52IBWSN-1001	78.00	20.73	90.00	122.63	6.68	12.00	21.02	35.40	35.01	36.99	13.10
52IBWSN-1002	79.00	19.13	92.20	126.63	7.08	9.80	22.02	30.40	42.21	40.19	12.30
52IBWSN-1003	83.00	18.33	94.00	129.63	6.08	10.80	20.62	32.60	34.41	38.79	12.70
52IBWSN-1004	77.00	19.73	94.00	122.63	7.28	11.20	26.42	39.50	37.41	35.69	14.10
52IBWSN-1005	77.00	22.93	83.20	124.63	6.48	12.00	21.02	29.60	38.81	40.59	12.10
52IBWSN-1006	80.00	22.93	85.00	128.63	7.08	11.60	19.32	40.40	33.41	36.39	14.70
52IBWSN-1007	81.00	21.73	88.00	132.63	6.28	11.80	25.02	34.00	39.41	39.59	13.50
52IBWSN-1008	83.00	24.93	89.00	133.63	7.68	12.60	22.02	41.00	40.41	35.89	14.70
52IBWSN-1009	79.00	21.73	88.00	126.63	7.68	13.20	21.62	29.80	41.41	40.39	12.10
52IBWSN-1010	82.00	17.73	88.80	125.63	7.88	11.60	22.42	36.00	40.01	39.59	14.30
COH-1105	84.00	20.73	91.20	128.63	8.08	12.40	22.82	39.40	41.81	34.79	13.70
MACS-5044	85.00	22.53	81.60	123.63	9.28	10.60	19.42	37.60	41.01	35.09	13.20
AKAW-4901	82.00	26.23	91.20	126.63	8.68	11.90	21.22	37.90	34.41	35.69	13.50
HD-2967 (c)	86.00	21.60	98.12	130.33	7.60	13.20	19.83	35.95	40.30	40.68	14.63
NW-5054 (c)	76.83	23.37	102.23	123.67	7.40	10.57	20.90	38.47	41.33	35.33	13.58
DBW-187 (c)	79.83	22.60	103.07	125.00	8.37	13.67	19.35	40.47	40.10	38.57	15.60
HD-2733 (c)	77.33	24.93	102.18	122.50	7.53	11.63	20.80	36.90	41.72	36.77	13.57
Mean	80.43	22.50	90.19	126.97	6.75	11.42	21.63	35.14	37.99	38.17	13.38
Min	75.25	17.73	80.15	121.88	5.08	8.20	15.22	29.35	32.66	34.11	11.60
Max	86.00	27.53	109.85	138.88	9.28	14.47	31.77	44.47	42.66	41.16	15.80
CV	1.51	2.00	0.94	1.81	3.31	18.91	5.47	1.78	2.13	2.94	4.04
Ci - Cj	1.49	0.55	1.05	2.82	0.28	2.66	1.46	0.77	0.99	1.38	0.66
BiVi - BiVj	3.65	1.36	2.57	6.91	0.68	6.51	3.57	1.88	2.44	3.38	1.63

BiVi - BjVj	4.08	1.52	2.87	7.72	0.75	7.28	3.99	2.10	2.72	3.78	1.82
Ci - VI	3.12	1.16	2.19	5.90	0.58	5.56	3.05	1.61	2.08	2.89	1.39

Table 3: Estimates of simple correlation coefficients between yield and yield and attributing traits in wheat

Traits	Day to 50% flowering	Peduncle length(cm)	Plant height (cm)	Days to maturity	Tillers /plant	Spike length (cm)	Flag leaf area (cm)	Biological yield/plant (g)	Test weight (g)	Harvest index (%)	Grain yield /plant (g)
Day to 50% flowering	1.00	0.886**	0.940**	0.990**	0.887**	0.928**	0.887**	0.932**	0.967**	0.989**	0.954**
Peduncle length(cm)		1.00	0.941**	0.911**	0.775**	0.814**	0.837**	0.932**	0.892**	0.878**	0.915**
Plant heigiht (cm)			1.00	0.964**	0.906**	0.905**	0.936**	0.943**	0.933**	0.931**	0.935**
Days to maturity				1.00	0.878**	0.924**	0.892**	0.959**	0.972**	0.978**	0.963**
Tillers /plant					1.00	0.866**	0.921**	0.842**	0.860**	0.868**	0.849**
Spike length (cm)						1.00	0.863**	0.901**	0.871**	0.936**	0.925**
Flag leaf area (cm)							1.00	0.858**	0.893**	0.879**	0.875**
Biological yield/plant (g)								1.00	0.942**	0.916**	0.978**
Test weight (g)									1.00	0.938**	0.933**
Harvest index (%)										1.00	0.959**

* &** Significant at 5% & 1% respectively

Table 4: Path coefficient direct and indirect effect of all other characters on grain yield

Traits	Day to 50% flowering	Peduncle length(cm)	Plant height (cm)	Days to maturity	Tillers /plant	Spike length (cm)	Flag leaf area (cm)	Biological yield/plant (g)	Test weight (g)	Harvest index (%)	Grain yield /plant (g)
Day to 50% flowering	0.629	-0.266	0.381	-1.259	-0.201	-0.200	0.110	1.131	-0.199	0.829	0.954**
Peduncle length(cm)	0.558	-0.301	0.381	-1.159	-0.176	-0.176	0.104	1.131	-0.184	0.735	0.915**
Plant heigiht (cm)	0.591	-0.283	0.405	-1.227	-0.205	-0.195	0.116	1.145	-0.192	0.780	0.935**
Days to maturity	0.623	-0.274	0.391	-1.272	-0.199	-0.200	0.111	1.164	-0.200	0.820	0.963**
Tillers /plant	0.558	-0.233	0.367	-1.116	-0.227	-0.187	0.114	1.022	-0.177	0.727	0.849**
Spike length (cm)	0.584	-0.245	0.366	-1.176	-0.196	-0.216	0.107	1.094	-0.179	0.785	0.925**
Flag leaf area (cm)	0.558	-0.252	0.379	-1.134	-0.209	-0.186	0.124	1.042	-0.184	0.737	0.875**
Biological yield/plant (g)	0.586	-0.280	0.382	-1.219	-0.191	-0.195	0.107	1.214	-0.194	0.768	0.978**
Test weight (g)	0.609	-0.268	0.378	-1.237	-0.195	-0.188	0.111	1.143	-0.206	0.786	0.933**
Harvest index (%)	0.622	-0.264	0.377	-1.244	-0.197	-0.202	0.109	1.113	-0.193	0.838	0.959**

R square = 0.994679, Residual effect = 0.072947

Bold values show direct and normal values shows indirect effects.

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