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Genetic Analysis of Bread Wheat (*Triticum aestivum* L. em. Thell.) Genotypes for Yield and its Component Traits

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Abstract

The present study has been conducted at the Agricultural Research Farm of B.R.D. (PG) College, Deoria in a randomized block design to evaluate the extent of variability, heritability and direct and indirect effects of component traits on grain yield. The experiment was planned in the *rabi* 2022 with fifteen elite wheat cultivars sourced from Banaras Hindu University, Varanasi. All the recommended cultural practices were adopted to raise a good crop. The data were observed on fourteen quantitative traits of wheat. The analysis of variance showed a good amount of variability present among these cultivars of wheat as all the genotypes were significant for all the traits at given probability levels. The traits days to 50% flowering (90.7%), plant height (cm) (87%), days to maturity (91%), spike length (cm) (85%), no. of spikeletes per spike (76%), 1000grain weight(g) (86%) and biological yield per plant(g) (87%) showed very high heritability in broad sense. Most of the traits showed moderate level of genetic advance in percent of mean like flag leaf area (25.39%), spike length (26.20%), number of grains par spike (20.51%), biological yield per plant (29.14%), grain yield per spike (20.51%) and harvest index (20.69%). The genotypic (GCV) as well as phenotypic coefficient (PCV) were high for the traits flag leaf area, spike length, no. of grains per spike, biological yield per plant, grain yield per plant and harvest index. At phenotypic level the characters plant height (0.4034), ear length (0.6521), no. of spikelets per spike (0.4467), grain weight per spike (0.5265) and harvest index (0.3643) showed a strong association with grain yield per plant. The traits days to 50% flowering (0.1192), peduncle length (0.2591), ear length (0.3714) and biological yield (0.7713) exerted high amount of direct effects while biological yield *via* test weight, ear length, plant height and harvest index *via* ear length, no. of spikelets per spike, biological yield and test weight possessed high indirect effects on yield.

Key words : *Grain yield, heritability, correlation coefficient, path coefficient, gcv, pcv.*

Introduction

Wheat, often hailed as the “monarch of cereals,” dominates the agricultural landscape due to its extensive cultivation, prolific yield, and prominent status in the global food grain arena. Hexaploid wheat, a synthesis of three genomes A, B, and D (1) comprises over 95% of today’s wheat production, integral to the creation of bread and various baked confections.

As an autogamous crop, wheat is extensively cultivated across numerous nations, including India. Key wheat-producing states encompass Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, Karnataka, West Bengal, Uttarakhand, Himachal Pradesh, and Jammu & Kashmir. These regions collectively account for approximately 99.5% of India’s total wheat output. Uttar Pradesh stands preeminent, contributing over 34% of the nation’s wheat yield. Within an expanse of 168 lakh hectares devoted to cultivation, wheat spans more than 96 lakh hectares, with Uttar Pradesh achieving yields surpassing 3,100 kg per hectare. According to the Second Advance Estimates for 2022-23, the nation’s wheat production is anticipated at 1121.82 LMT, marking an increase of 44.40 LMT compared to the preceding year (2).

The presence of genetic variability is a fundamental prerequisite for enhancing wheat varieties through systematic breeding programs. Numerous studies, conducted both domestically and internationally, have focused on assessing genetic variability, correlation coefficients, and the direct and indirect impacts of various traits on seed yield of wheat genotypes in diverse environments. The substantial genetic variability in the foundational material ensures a greater likelihood of developing targeted plant types (3, 4).

Exploring the nexus between various characteristics and grain yield, correlation studies coupled with path analysis offer profound insights for breeders during selection processes. These studies illuminate the

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magnitude and trajectory of the interplay between yield and its contributory traits. Path coefficient analysis, by quantifying both direct and indirect influences of independent variables on dependent variables, aids breeders in identifying yield components and discerning the causality of associations between variables (5). This analysis yields invaluable information, facilitating indirect selection for genetic yield enhancement, especially when direct selection proves ineffectual for traits with low heritability, such as yield.

Materials and Methods

The current field experiment was carried out during the rabi season of 2022-23 at the Agricultural Research Farm of Baba Raghav Das Post Graduate College, Deoria, Uttar Pradesh. This institution is geographically positioned in eastern Uttar Pradesh, India, at 26.5°N latitude, 83.79°E longitude, and an elevation of 68 meters (223 feet) above sea level. The climate of Deoria is semi-arid, featuring hot summers and cold winters, with nearly 80% of the total annual rainfall occurring during the monsoon season, which ends in September, with sporadic showers during winter.

The experimental material included fifteen elite wheat cultivars, one of which served as a check variety. These were sourced from the Department of Genetics and Plant Breeding at Banaras Hindu University, Varanasi, and were sown in a Randomized Block Design with three replications during the rabi season of 2022-23. Standard agricultural practices were followed to ensure optimal crop growth, maintaining row spacing at 22 cm and plant spacing at 5 cm.

To assess yield, contributing traits, and seed characteristics, five plants were randomly tagged for observation. The mean value for each treatment was determined by averaging these observations. The traits studied and the methodologies used are as follows: Days to 50% flowering, Days to maturity, Plant height (cm), Number of effective tillers per plant, Peduncle length (cm), Flag leaf area (cm²), Length of spike (cm), Number of spikelets per spike, Number of grains per spike, Grain weight per spike (g), Thousand grain weight (g), Grain yield per plant (g), Biological yield per plant (g), and Harvest index (%).

The experimental data collected for these fourteen traits across fifteen wheat genotypes, including the check variety, were compiled by averaging the values of selected plants in each plot. These data were then subjected to the following statistical analyses: Analysis of variance (6), Coefficient of variation (7), Estimation of Heritability, Genetic advance as a percentage of the mean Correlation coefficient (10) and Path coefficient analysis (5).

Results and Discussion

Analysis of variance : The Analysis of variance (ANOVA) indicated that the mean sum of squares due to genotypes were highly significant for all the traits under investigation. Tarkeshwar *et al.* (2019), Sahu *et al.* (2019), Kumar *et al.* (2020a) and Chaudhary (2022) also noted significant (11) variation for days to 50% flowering, spike length, plant height, biological yield, harvest index and grain yield per plant. The mean sum of squares due to replication showed non-significant differences for all the traits under study indicating good homogeneity among replications. Mean sum of square from analysis of variance for various traits are given in Table-1.

Variability, heritability (broad sense) and genetic advance over mean : Genotypic and phenotypic coefficient of variation (GCV and PCV) (%), heritability (%) in broad sense, genetic advance and genetic advance as per cent of mean (genetic gain) for each trait are presented in Table-2. The presence of adequate genetic variability is essential and its consideration combined with heritability (broad sense) may play a significant role in analysis the relative contributions of genetic and non-genetic factors to the total phenotypic variation in a population. To obtain a clear picture about the variability in all the genotypes, the variability was further partitioned into phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). Heritability and genetic advance are important selection parameters. Heritability estimated along with genetic advance are normally more helpful in predicting the grain under selection than heritability estimates due to alone. The estimate of heritability can be utilized for the prediction of genetic gain which indicates the genetic improvement that would result from the selection of best individual.

Hence GCV was recorded highest for flag leaf area (15.71%) followed by biological yield per plant (15.12%), spike length (13.78%), grain weight per spike (13.26%), no. of grains per spike (13.26%), harvest index (12.94%), no of spikelets per spike (10.4%), grain yield per plant (8.63%), 1000 grain weight (7.94%), peduncle length (7.32%), days to 50% flowering (5.37%), plant height (4.61%) and plant height (4.61%) and days to maturity (4.44%) exhibited low genotypic coefficient of variation. The PCV was higher in magnitude than that of genotypic coefficient of variation for all the characters under study. The highest value for PCV was recorded for flag leaf area (20.03%) followed by grain yield per spike (17.65%), no. of grains per spike (17.65%), harvest index (16.67%), biological yield (16.16%), spike length (14.92%), grain yield per plant (11.88%), no of spikelets per spike (11.83%) The characters *viz.,* days to maturity (4.63 %)

Table-1 : Analysis of variance of Randomized Block Design for fourteen characters of wheat Germplasm.

Sr. No.	Characters	Source of variation		
		Replication (df=2)	Genotype (df=14)	Error (df=28)
1.	Days to 50% flowering	0.68	51..55**	1.68
2.	Days to maturity	0.60	91.67**	2.64
3.	Plant height (cm)	7.40	54.14**	2.52
4.	Peduncle length (cm)	2.18	24.14**	2.96
5.	Flag leaf area (cm^2)	25.99	112.23**	19.34
6.	Number of productive tillers per plant	0.00	0.19**	0.04
7.	Ear length (cm)	0.73	6.88**	0.37
8.	Number of spikelets per spike	0.44	13.36**	1.24
9.	Number of grains per spike	12.84	185.50**	37.97
10.	Grain weight per spike (g)	0.007	0.31**	0.09
11.	1000-grain weight (g)	3.20	38.67**	1.89
12.	Biological yield per plant (g)	0.03	40.43**	1.83
13.	Grain yield per plant (g)	0.58	0.26**	0.51
14.	Harvest index (%)	17.36	87.44**	15.74

*, ** Significant at P = 5% and 1% respectively.

Table-2 : Estimates of range, mean, heritability and genetic advance in 15 germplasm lines of wheat.

Characters	Range			Variance		Coefficient of variation		H^2 (bs) (%)	GA (%)	GAM
	Min.	Max	Mean	^2_g	^2_p	GCV (%)	PCV (%)			
Days of 50% flowering	70	88	75.88	16.62	18.31	5.37	5.63	90.70	8.00	10.544
Flag leaf area	111	138	89.06	30.96	50.30	15.71	20.03	61.55	8.99	25.39
Plant height (cm)	80.4	98.2	36.29	17.20	19.73	4.61	4.94	87.00	7.97	8.87
Days to maturity	28.08	43.88	35.40	29.67	32.32	4.44	4.63	91.00	10.75	8.77
Spike length (cm)	20.57	53.74	10.69	2.17	2.54	13.78	14.92	85.00	2.80	26.20
No. of spikeletes per spike	4.2	5.8	5.28	4.03	5.28	10.34	11.83	76.00	3.61	18.61
No. of productive tiller per plant	6.58	13.32	19.43	0.04	0.09	4.13	5.85	49.00	0.31	6.00
Peduncle length(cm)	15.8	23	122.6	7.05	10.02	7.32	8.72	70.00	4.59	12.65
No of grains per spike	37.4	70.8	52.90	49.17	87.15	13.26	17.65	56.00	10.85	20.51
1000 grain weight (g)	1.64	3.48	2.34	12.26	14.15	7.94	8.53	86.00	6.71	15.23
Biological yield per plant (g)	50	37	23.57	12.86	14.69	15.12	16.16	87.00	6.91	29.14
Grain yield per plant(g)	15.41	31.16	8.93	0.58	1.09	8.63	11.88	52.00	1.14	12.93
Grain yield per spike (g)	6.68	11.52	44.37	49.17	87.15	13.26	17.65	56.00	10.85	20.51
Harvest index (%)	23.45	49.42	36.45	23.89	39.64	12.94	16.67	60.00	7.81	20.69

showed low phenotypic coefficient of variation. (11) observed higher GCV and PCV for grain yield per plant, biological yield per plant, ear weight, number of ears per plant and peduncle length. (12) noted higher GCV and PCV for number of grains per spike, number of tillers per meter row, grain yield, harvest index and 1000-grain weight. (13) in their studies found harvest index, biological yield grain yield and some other associates had maximum genotypic and phenotypic coefficient of variation.

Broad sense heritability was estimated for all the characters under study. High heritability was observed for most of the traits and it was noted highest for days to maturity (91%) followed by days to 50% flowering (90%), plant height (87%), biological yield (87%), 1000 grain weight (86%), spike length (85%), no of spikelets per spike (76%), peduncle length (70%), flag leaf area (61.55%) and harvest index (60%), while grain yield per spike (56%), no of grains per spike (56%), grain yield per plant (52%) and number of productive tiller per plant(49%) exhibited moderate estimates of heritability. The high genetic advance as per cent of mean (genetic gain) was recorded for biological yield per plant (29.14%) followed by spike length (26.20%) and flag leaf area (25.39%), harvest index (20.69), grain yield per spike (20.51%), no. of grains per spike (20.51%), number of spikelets per spike (18.61%), 1000 grain weight (15.23%), peduncle length (12.65%), days of 50% flowering (10.54%), days to maturity (8.77%) and number of productive tiller per plant (6.00%) showed low genetic gain. (13) recorded the high estimates of heritability in broad sense for plant height, spike length, and peduncle length. Chaudhary (2022) observed high heritability accompanied with high genetic advance for flag leaf area and grain weight while values

Table-3 : Estimates of phenotypic correlation coefficients among fourteen metric traits of wheat germplasm.

Characters	Days to 50% flowering	Plant height (cm)	Peduncle length (cm)	Flag leaf area	Ear length (cm)	No. of productive tiller per plant	No. of spikelets per spike	Days to maturity	No. of grains per spike	Grain weight per spike	Biological yield (g)	1000-grain weight (g)	Harvest index (%)	Grain yield/ Plant (g)
DFF	1.0000	0.3622*	0.1579	0.0899	0.1155	-0.0887	0.1156	0.4384**	-0.2118	-0.0733	-0.0144	-0.0662	0.014	0.1119
PHT (cm)		1.0000	-0.0677	0.064	0.6066**	0.0834	0.5336**	0.5543**	0.2121	0.3423*	0.2055	-0.123	0.104	0.4034**
PL (cm)			1.0000	0.7007**	-0.1161	-0.2348	-0.2926	0.4888**	-0.0847	-0.0806	-0.0386	-0.2149	-0.0445	0.0073
FLA				1.0000	-0.1259	-0.2005	-0.109	0.3325*	0.1002	0.011	-0.0663	-0.1931	-0.0092	-0.0264
EL (cm)					1.0000	-0.1635	0.6726**	0.4853**	0.1623	0.453**	0.2176	0.1462	0.1719	0.6521**
TPP						1.0000	-0.0603	-0.2169	0.0132	-0.0846	-0.1067	0.0354	-0.0155	-0.133
SPS							1.0000	0.2382	0.4798**	0.5298**	-0.0253	-0.1807	0.3292*	0.4467**
DTM								1.0000	0.0088	0.1156	0.1367	-0.085	0.0156	0.2419
GPS									1.0000	0.654**	-0.082	-0.2871	0.1732	0.0388
GWPS										1.0000	0.142	-0.138	0.2486	0.5265**
BY (g)											1.0000	0.5788**	-0.7215**	0.2539
TW (g)												1.0000	-0.5643**	0.0792
HI (%)													1.0000	0.3643*

*, ** Significant at P = 5% and 1% respectively.

Table-4 : Direct and indirect effects of 13 traits on grain yield per plant in wheat at phenotypic level.

Characters	Days to 50% flowering	Plant height (cm)	Peduncle length (cm)	Flag leaf area	Ear length (cm)	No. of productive tiller per plant	No. of spikelets per spike	Days to maturity	No. of grains per spike	Grain weight per spike	Biological yield (g)	1000-grains weight (g)	Harvest index (%)	Grain yield/ Plant (g)
DFF	0.11924	-0.00716	0.04092	0.00294	0.0429	-0.00624	0.00765	-0.10966	0.04271	-0.01545	-0.01111	-0.00743	0.01258	0.1119
PHT (cm)	0.04319	-0.01977	-0.01757	0.00209	0.22533	0.00591	0.03537	-0.13861	-0.04277	0.07199	0.1586	-0.01389	0.09344	0.4034**
PL (cm)	0.01883	0.00134	0.25913	0.02294	-0.04316	-0.0166	-0.0194	-0.12223	0.01708	-0.01686	-0.02978	-0.02411	-0.03998	0.0073
FLA	0.01072	-0.00127	0.18158	0.03273	-0.04673	-0.01417	-0.00722	-0.08315	-0.02021	0.00229	-0.05114	-0.02167	-0.00827	-0.0264
EL (cm)	0.01377	-0.01199	-0.03011	-0.00412	0.37146	-0.0116	0.04459	-0.12136	-0.03271	0.09526	0.16778	0.01639	0.15453	0.6521**
TPP	-0.01053	-0.00165	-0.06082	-0.00656	-0.06092	0.07086	-0.004	0.05429	-0.00266	-0.01808	-0.08254	0.00395	-0.01384	-0.133
SPS	0.01377	-0.01055	-0.07585	-0.00357	0.24992	-0.00427	0.06628	-0.05957	-0.09676	0.11122	-0.01952	-0.02027	0.29577	0.4467**
DTM	0.05229	-0.01096	0.12667	0.01088	0.18027	-0.01535	0.01579	-0.25007	-0.00177	0.02424	0.10545	-0.00954	0.01402	0.2419
GPS	-0.02525	-0.00419	-0.02195	0.00328	0.06025	0.00093	0.0318	-0.0022	-0.20166	0.13764	-0.06325	-0.0322	0.15561	0.0388
GWPS	-0.00876	-0.00677	-0.02078	0.00036	0.16834	-0.00608	0.03507	-0.02883	-0.13205	0.21032	0.10954	-0.01551	0.22335	0.5265**
BY (g)	-0.00172	-0.00406	-0.01	-0.00217	0.08079	-0.00757	-0.00168	-0.03418	0.01654	0.02985	0.77139	0.06494	-0.64823	0.2539
TW (g)	-0.00789	0.00245	-0.05569	-0.00632	0.05427	0.00249	-0.01198	0.02126	0.05788	-0.02905	0.44648	0.1122	-0.50699	0.0792
HI (%)	0.00167	-0.00206	-0.01153	-0.0003	0.06389	-0.00109	0.02182	-0.0039	-0.03493	0.05225	-0.55656	-0.06331	0.89845	0.3643*

recorded for test weight, grain yield per plant, number of spikelets per spikes. The high estimates of heritability were observed for days to maturity, plant height, number of productive tillers per plant, number of grains per spike, 1000-grain weight (g), grain yield per plant (g), harvest index (%), and protein content (%) in both F_1 and F_2 generations by (3) observed high heritability in a broad sense associated with high genetic advance as percent mean (GAM) was for biological yield per plant, grains per spike and grain yield per plant.

Correlation coefficient analysis : Correlation coefficient at phenotypic levels were estimated for 14 characters in 15 genotypes of wheat to study the degree of mutual relationship between yields and its component traits. The estimated phenotypic correlation coefficients are present in Table-3 respectively. Days to 50% flowering exhibited positive and significant correlation with plant height (0.362) and days to maturity (0.438) and showed negative and non-significant correlation with grain weight per spike (-0.07), no. of grains per spike (-0.211), biological yield (-0.014) and 1000-grain weight (-0.066) at phenotypic levels. Plant height exhibited positive and significant correlation with ear length (0.606), no. of spikelets per spike (0.533), days to maturity (0.554), grain weight per spike (0.3423) and grain yield/plant (0.403) and showed negative and non significant correlation with 1000-grain weight (-0.123) at phenotypic level.

Peduncle length exhibited positive and significant correlation with flag leaf area (0.7007) and days to maturity (0.488) and showed negative and non significant correlation with ear length (-0.116), no. of spikelets per spike (-0.292), no. of productive per plant (-0.23), no. of grains per spike (-0.08). Flag leaf area exhibited positive and significant correlation with days to maturity (0.332) and peduncle length (0.70) and showed negative and non significant correlation with ear length (-0.12), no. Of productive tillers per plants (-0.20), no of spikelets per spike (-0.109) and biological yield (-0.06) at phenotypic level. Ear length exhibited positive and significant correlation with number of spikelets per spike (0.672), plant height (0.606), days to maturity (0.485) grain weight per spike (0.453) and grain yield per plant (0.6521) and showed negative and non significant correlation with no of productive tiller per plant (-0.16) and flag leaf area (-0.12) at phenotypic level.

Number of productive tillers per plant exhibited negative and non significant correlation with number of spikelets per spike (-0.06), days to maturity (-0.21), grain weight per spike (-0.084),biological yield (-0.10) and harvest index (-0.13), days to 50% flowering(-0.08), peduncle length (-0.23) whereas number of spikelets per spike exhibited positive and significant correlation with number of grains per spike (0.479), plant height (0.53), ear length (0.67), grain weight per spike (0.529) and harvest index (0.329) and grain yield per plant (0.446). Days to maturity exhibited positive and significant correlation with days to 50% flowering (0.43), plant height (0.55), peduncle length (0.48), flag leaf exhibited non significant correlation with no. of grains per spike (0.008), grain weight per spike (0.115) and biological yield (0.136) at phenotypic level.

Number of grains per spike exhibited positive and significant correlation with grain weight per spike (0.654) and no of spikelet per spike (0.47) at phenotypic level. Grain weight per spike exhibited positive and significant correlation with grain yield per plant (0.526), plant height (0.34), ear length (0.45), no of spikelet per spike (0.52) and grain per spike (0.65) while biological yield per plant exhibited positive and significant correlation coefficient with 1000- grain weight (0.578) and negative correlation with harvest index (-0.72),days to 50%flowering (-0.01), peduncle length (-0.03), flag leaf area (-0.06),tillers per plant (-0.10) and no of spikelets per spike (-0.02) at phenotypic level.

Grain yield per plant exhibited positive and significant correlation with plant height (0.403), ear length (0.652), no of spikelets per spike (0.446), grain weight per spike (0.526) and harvest index (0.36); and the 1000-grains weight exhibited positive and significant with biological yield (0.57) and negative and significant correlation with harvest index (0.564), days to 50%flowering (-0.06), plant height (-0.12), peduncle length (-0.21), flag leaf area (-0.19), spikelets per spike (-0.18) while harvest index show highly significant and positive with grain yield/plant (0.364), plant height (0.40), ear length (0.65), spikelet per spike (0.44) and grain weight per spike (0.52) at phenotypic levels. (14, 15) noticed strong association of yield attributes with grain yield per plant.

Path coefficient analysis : Path coefficient analysis was conducted to assess the magnitude of contribution of various yield contributing traits to yield in the form of cause and effect. Grain yield per plant was taken as dependent variable and rest 13 traits were treated as independent variables. It revealed whether the association of these independent characters with yield is due to their direct effect on yield or is consequence of their indirect effect *via* other component characters. The direct and indirect effects of 14 characters on grain yield per plant estimated by path coefficient analysis using simple correlations are given in table-4.

At phenotypic level, highest positive direct effect on grain yield per plant was exerted by harvest index (0.898) followed by biological yield (0.7713), ear length (0.371), peduncle length (0.259), days to 50%flowering (0.11), flag leaf area (0.03), no of productive tiller per plant (0.07). Remaining characters plant height (-0.019) and days to maturity (-0.25) contributed negative direct effect on grain yield per plant.

The trait plant height *via* ear length (0.2253), and biological yield (0.1586); flag leaf area *via* peduncle length (0.1815); ear length *via* biological yield (0.1677) and harvest index (0.1545); spikelets per spike *via* ear length (0.2499), grains weight per spike (0.1112) and harvest index (0.2957); days to maturity *via* peduncle length (0.1266) and ear length (0.1802); number of grains per spike *via* grain weight per spike (0.1376) and harvest index (0.1556); grains weight per spike *via* ear length (0.1683) and harvest index (0.2233);biological yield and test weight *via* harvest index (0.6382 and 0.5069) exhibited substantial amount of indirect effects on grain yield per plant also found almost similar results of yield contributing traits exhibited considerable direct and indirect effects on economic yield in wheat.

Conclusion

In a nutshell, the present study revealed the presence of substantial amount of variation among various genotypes of wheat. The presence of high heritability along with high or moderate genetic advance for the traits biological yield per plant, spike length and flag leaf area, harvest index, grain yield per spike and no. of grains per spike pertained additive gene action indicating selection as an imported breeding tool for the development of high yielding varieties for these characters. The association and path coefficient analysis showed strong interrelationship among various metric traits in wheat.

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