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Ajeet Jaiswal
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Lokendra Singh
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Mahak Singh
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Som Veer Singh
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Sarvendra Kumar
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

AL Jatav
Department of Seed Science and Technology, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

RK Singh
Department of Agricultural Statistics and Economics, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Corresponding Author:
Ajeet Jaiswal
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Analysis of correlation and path coefficient for yield and yield related traits in wheat genotypes

Ajeet Jaiswal, Lokendra Singh, Mahak Singh, Som Veer Singh, Sarvendra Kumar, AL Jatav and RK Singh

Abstract
The present research work was conducted at Crop Research Farm, Nawabganj, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.), India. The experimental material for present investigation comprised of 100 treatments including 45 F_2s, 45 F_1s and 10 parents *viz*., DBW-88, K-1313, DBW-107, K-9423, DBW-90, HI-8699, DBW-14, K-1006, HD-3059 and HD-2967 were evaluated in RBD followed by half diallel mating design for the study of correlation and path coefficient analysis for fifteen characters, *viz*., days to 50 per cent flowering, plant height, days to maturity, number of productive tillers per plant, flag leaf area, spike length, number of spikelets per spike, number of grains per spike, biological yield per plant, grain yield per plant, 1000-grain weight, harvest index, protein content, phenol colour and seed hardness in wheat. The study of correlation revealed that grain yield per plant strongly associated with number of productive tillers per plant and biological yield per plant in both F_1 and F_2 generation at both genotypic and phenotypic level. Path analysis revealed that 1000-grain weight, biological yield per plant, harvest index, seed hardness and protein content showed positive direct effect on grain yield per plant in both F_1 and F_2 generation at both genotypic and phenotypic level.

Keywords: Correlation coefficient, path coefficient, genotypes, diallel mating design

Introduction
Wheat belongs to the tribe Triticeae in the grass family Poaceae (Gramineae). Wheat plant has several flowered spikelets arranged alternately in opposite sides of the rachis forming a true spike. Linnaeus in 1753 first classified wheat. In 1918, Sakamura [12] reported the chromosome number sets (genomes) for each commonly recognized type. This was a turning point in Triticum classification, depending on ploidy levels, wheat is of three types *viz.*, Diploid 14 (n=7), alloteraploid 28 (n=14) and allohexaploid 42 (n=21). Wheat is one of the most important staple food amongst major cereals of the world, occupying 17 % of crop acreage worldwide, feeding about 40 % of the world population and provide 20 % of the total food calories and protein in human nutrition. Wheat grain contains 2-3 % germ, 13-17 % bran (outer layers of wheat grain) and 80-85 % mealy endosperm on dry matter basis (Belderok *et al*. 2000) [5]. Bran is rich in vitamin B and minerals. The endosperm mainly contains food reserves which are needed for growth of the seedling. Endosperm contains fats (1.5%) and proteins (13%), albumins, globulins and the major proteins of the gluten complex- glutenins and gliadins-proteins that will form the gluten at dough stage.
The aim of correlation coefficient study is to find out the degree and direction of the relationship between two or more variables based on statistical measurement. It also clears suitability for indirect selection on any particular trait may or may not be effective as compared to other traits which associated with grain yield. Searle, (1965) [13] studied the various characters of wheat in F_1 and F_2 generations associated with grain yield. According to our findings (Table 1a, 1b, 2a, 2b, 2c and 2d) exhibited association and path performance at genotypic and phenotypic levels. The knowledge of genetic correlation and direct effects existing between yield and its components are essential for effective selection programme.

Material and Methods
The present research work was carried out at Crop Research Farm, Nawabganj, C.S. Azad University of Agriculture and Technology, Kanpur-208002 (U.P.) during *Rabi*, 2019-20. The experimental material comprised of 100 treatments (45 F_1s + 45 F_2s + 10 parents). Ten parental lines *viz.*, DBW-88, K-1313, DBW-107, K-9423, DBW-90, HI-8699, DBW-14, K-1006, HD-3059 and HD-2967 were used to develop combinations following half diallel mating design in wheat. The experimental material was sown in Randomized Block Design with three replications. The entries were sown in a 3 m length with inter and intra-row spacing of 22.5 cm and 10 cm, respectively. Plot size was single row for parents and F_1 while two row for F_2. Five plant sample for parent and F_1 and 10 plants sample were taken in F_2 for study. The individual plant data of the sample were recorded in each treatment of all replications for all the fifteen characters.

Correlation coefficients: The genotypic and phenotypic coefficient of correlation was calculated as suggested by Al-Jibouri *et al*., (1958) [3].

The significance of phenotypic correlation was tested against 'r' values from 'r' Table of Fisher and Yates (1938) [8] at (n-2) degree of freedom where 'n' is number of treatments.

Path coefficients: Path coefficient analysis was carried out according to Dewey and Lu (1959) [6].

Results and Discussion

Correlation coefficient:

The grain yield, among all the characters referred as the superior character which results from multiplicative interaction of several other characters that formed as yield components Thus, identification of important yield components and information about their interrelationship with each other will be very useful for developing the efficient breeding strategy for developing high yielding varieties. Such types of study generally expedite the selection of constraints and difficulties in the material for the simultaneous improvement of grain yield and its components. Among the all 15 characters, number of tillers per plant and biological yield per plant were significantly and positively correlated with grain yield per plant at both phenotypic and genotypic level in F_1 and F_2 generation. It indicated that simultaneous improvement of spike length, number of spikelets per spike and protein content will be helpful in selection for these traits towards the higher productivity. The positive correlation of grain yield per plant with number of tillers per plant and biological yield per plant were also reported by Lad *et al.* (2003) [9] and Dhanda *et al.* (2018) [7].

In this study, the few developmental traits were positive and showed significant association with other morphological traits. The results obtained in F_1 and F_2 generations are:

Significant and positive associations/correlation were observed in F_1 generation for days to 50% flowering with days to maturity and number of productive tillers per plant; plant height with seed hardness; days to maturity with number of productive tillers per plant; number of productive tillers per plant with biological yield per plant, protein content and grain yield per plant; spike length with number of spikelets per spike and number of grains per spike; number of spikelets/spike with number of grains per spike; 1000-grain weight with seed hardness and biological yield with grain yield per plant at both phenotypic and genotypic levels while number of tillers per plant with spike length and number of spikelets per spike at genotypic level only.

In F_2 generation levels, significant and positive correlation were observed for days to 50% flowering with days to maturity and number of productive tillers per plant, number of spikelets per spike; number of productive tillers per plant with spike length, biological yield per plant, protein content and grain yield per plant; spike length with number of spikelets per spike, number of grains per spike; number of spikelets per spike with number of grains per spike, biological yield per plant; 1000-grain weight with protein content and biological yield per plant with grain yield per plant in F_2 generation at both genotypic and phenotypic level while number of tillers per plant with number of spikelets per spike and harvest index with seed hardness and protein content at genotypic level. The association of grain yield with number of productive tillers per plant and biological yield per plant was strong at genotypic level than phenotypic ones.

The correlation coefficient which provides the symmetrical measurement of the degree of association between two variables or characters to help us for understanding the nature and magnitude of association among yield and yield contributing traits. In some situations, one may get the high association between two variables when no one exists in practice. It is assumed that such happened due to small sample size. In this study, the magnitude of genotypic correlations was greater than phenotypic ones, which was supported by the finding of Ahmad *et al*., (1978) [2]. Hence, it can be inferred that significant phenotypic correlation between traits is due to genetic causes, which may be due to pleiotropic effect rather than linkage between genes affecting directly to the characters.

The association of characters with grain yield in the F_2 generation (Table 1b) genotypic level were more frequent and formed strong association indirectly with the number of tillers per plant and biological yield per plant. It indicated that additive genetic variance was more prevalent for expression in respect of grain yield. Ahmad and Murty (1972) [1] also reported the genetic correlations for few developing traits in wheat. The implication of breeding methodology: The present investigation as given fruitful results has revealed suitable selection breeding methodology on the basis of genetic information in F_1 hybrids and F_2 segregating population.

Path coefficient (direct and indirect effects):

The path analysis provides an effective means for examining specific forces responsible to produce a given correlation. The method of path analysis depends on the combination of knowledge of degree of correlation among the variables in a system and helps us to know the casual and effect relations. In cases where the casual relations are uncertain, the method can be used to find out the logical consequences of any particular hypothesis in regard to them. The path coefficients analysis was carried out according to the method proposed by Dewey and Lu (1959) [6], through partitioning of total correlation into direct and indirect effects to get actual information for the contribution of different components traits towards grain yield. The biological yield per plant had highest positive and direct effects on seed yield at genotypic level and phenotypic level.

Days to 50 per cent flowering, number of spikelets per spike, 1000-grain weight, biological yield per plant, harvest index, phenol color, seed hardness and protein content exerted positive direct effect on seed yield per plant, whereas plant height, days to maturity, number of productive tillers per plant, flag leaf area and number of grains per spike exerted negative direct effect on seed yield per plant at genotypic and phenotypic level in F_1 generation.

Number of productive tillers per plant, flag leaf area, number of grains per spike, 1000-grain weight, biological yield per plant, harvest index, seed hardness and protein content exerted positive direct effect on grain yield per plant at both level and days to 50 per cent flowering in F_2 generation whereas plant height, days to maturity, spike length, number of spikelets per spike and phenol color exerted negative direct effect on seed yield per plant at genotypic and phenotypic level and days to 50 per cent flowering in F_2 generation. Mohammad *et al.* (2005 [11], 2008 [10]) also reported positive direct effect on grain yield for biological yield per plant and harvest index; Tripathi *et al* (2011) [14] and Awinash *et al*. (2015) [4] found positive direct effect on grain yield for 1000-grain weight, biological yield per plant and harvest index.

The residual effects were ranged from 0.0443-0.0638. The residual effect determines how best the causal factors account for the variability of the dependent variable i.e. grain yield per plant. The low estimate of residual effect suggested that most of the important traits contributing to yield have been included in the study.

Table 1a: Estimates of genotypic (rg) upper diagonal and phenotypic (rp) lower diagonal correlation coefficients among 15 characters in F_1 generation in wheat (*Triticum aestivum* L.)

rg rp	**Days to 50% flowering**	**Plant height (cm)**	**Days to maturity**	**No. of Tillers/ plant**	**Flag leaf area (cm^2)**	**Spike length (cm)**	**No. of spikelets/ spike**	**No. of grains/ spike**	**Biological yield/ plant(g)**	**1000-grain weight (g)**	**Harvest index (%)**	**Protein content (%)**	**Phenol colour**	**Seed hardness**	**Grain yield/plant**
Days to 50% flowering	**1.000**	-0.288*	0.949**	0.475**	-0.209	0.230	0.023	-0.004	-0.097	-0.042	0.014	0.133	0.149	-0.361**	-0.088
Plant height (cm)	-0.257	**1.000**	-0.366**	-0.240	-0.001	0.021	-0.066	-0.092	0.049	-0.133	-0.045	-0.332*	-0.078	0.293*	0.026

Days to maturity	0.924**	-0.319*	**1.000**	0.479**	-0.332*	0.193	0.053	-0.024	-0.093	-0.007	0.000	0.207	0.195	-0.294*	-0.092
No. of tillers/plant	0.421**	-0.233	0.426**	**1.000**	-0.031	0.275*	0.284*	0.147	0.358**	0.135	0.071	0.532**	0.099	-0.159	0.393**
Flag leaf area (cm^2)	-0.191	0.000	-0.298*	-0.031	**1.000**	0.039	0.123	0.094	-0.011	0.021	-0.038	-0.005	-0.108	0.012	-0.032
Spike length (cm)	0.208	0.022	0.165	0.263	0.038	**1.000**	0.806**	0.609**	-0.051	0.100	0.218	-0.011	-0.227	0.012	0.056
No. of spikelets/spike	0.004	-0.064	0.030	0.266	0.116	0.790**	**1.000**	0.623**	0.118	0.128	0.083	0.003	-0.273*	0.166	0.167
No. of grains/spike	0.002	-0.089	-0.014	0.145	0.092	0.599**	0.612**	**1.000**	0.077	0.198	0.162	0.106	-0.109	0.022	0.162
Biological yield/plant(g)	-0.089	0.051	-0.083	0.354**	-0.012	-0.050	0.111	0.075	**1.000**	0.010	-0.281*	-0.056	-0.087	-0.023	0.874**
1000-grain weight(g)	-0.040	-0.132	-0.008	0.133	0.021	0.098	0.123	0.194	0.009	**1.000**	0.233	0.242	0.044	0.298*	0.139
Harvest index (%)	0.011	-0.046	0.002	0.077	-0.038	0.211	0.080	0.153	-0.281	0.227	**1.000**	0.254	-0.220	0.008	0.217
Protein content (%)	0.125	-0.328*	0.187	0.519**	-0.004	-0.010	-0.003	0.103	-0.056	0.240	0.246	**1.000**	0.028	-0.078	0.072
Phenol color	0.138	-0.066	0.180	0.099	-0.100	-0.214	-0.242	-0.098	-0.079	0.042	-0.210	0.034	**1.000**	-0.080	-0.190
Seed hardness	-0.335*	0.290*	-0.266	-0.153	0.011	0.012	0.158	0.023	-0.022	0.297*	0.007	-0.078	-0.080	**1.000**	-0.002
Grain yield/plant	-0.084	0.027	-0.082	0.392**	-0.033	0.055	0.158	0.155	0.870**	0.138	0.225	0.069	-0.177	-0.001	**1.000**

*Significant at 5% level, **Significant at 1% level.

Table 1b: Estimates of genotypic (rg) upper diagonal and phenotypic (rp) lower diagonal correlation coefficients among 15 characters in F_2 generation in wheat (*Triticum aestivum* L.)

rg rp	**Days to 50% flowering**	**Plant height (cm)**	**Days to maturity**	**No. of Tillers/ plant**	**Flag leaf area (cm^2)**	**Spike length (cm)**	**No. of spikelets / spike**	**No. of grains/ spike**	**Biological yield/plant (g)**	**1000-grain weight (g)**	**Harvest index (%)**	**Protein (%)**	**Phenol color**	**Seed hardness**	**Grain yield/plant**
Days to 50% flowering	**1.000**	-0.056	0.858**	0.289*	-0.406**	0.209	0.296*	0.173	0.136	0.023	-0.057	0.139	0.017	-0.073	0.112
Plant height (cm)	-0.056	**1.000**	-0.102	-0.319*	0.153	0.115	0.051	-0.057	-0.100	-0.091	-0.087	-0.342*	-0.092	0.076	-0.143
Days to maturity	0.832**	-0.095	**1.000**	0.240	-0.376**	0.046	0.214	0.062	0.146	-0.038	-0.066	0.088	0.054	0.016	0.118
No. of tillers/plant	0.280*	-0.312*	0.225	**1.000**	-0.224	0.305*	0.272*	0.263	0.320*	0.160	-0.048	0.543**	0.163	-0.064	0.318*
Flag leaf area (cm^2)	-0.396**	0.148	-0.359**	-0.218	**1.000**	-0.099	-0.194	-0.054	-0.166	-0.080	0.245	-0.114	-0.077	-0.061	-0.072
Spike length (cm)	0.199	0.109	0.043	0.294*	-0.099	**1.000**	0.816**	0.525**	0.247	0.143	-0.203	0.030	0.187	-0.157	0.165
No. of spikelets/spike	0.277*	0.046	0.198	0.256	-0.185	0.798**	**1.000**	0.562**	0.312*	0.057	-0.182	-0.059	-0.004	-0.044	0.236
No. of grains/spike	0.164	-0.057	0.061	0.253	-0.054	0.520**	0.574**	**1.000**	0.194	0.121	0.021	0.017	0.028	0.039	0.201
Biological yield/plant(g)	0.136	-0.097	0.144	0.315*	-0.159	0.236	0.293*	0.186	**1.000**	-0.205	-0.151	0.072	0.119	-0.034	0.931**
1000-grain weight(g)	0.023	-0.090	-0.035	0.157	-0.079	0.140	0.055	0.118	-0.208	**1.000**	0.142	0.389**	0.154	0.242	-0.142
Harvest index (%)	-0.057	-0.074	-0.059	-0.039	0.228	-0.190	-0.165	0.021	-0.171	0.133	**1.000**	0.273*	-0.141	0.273*	0.215
Protein content (%)	0.137	-0.338*	0.082	0.530**	-0.111	0.029	-0.055	0.018	0.073	0.388**	0.253	**1.000**	0.012	0.213	0.193
Phenol color	0.017	-0.083	0.057	0.159	-0.070	0.158	-0.006	0.027	0.119	0.147	-0.126	0.014	**1.000**	0.043	0.064
Seed hardness	-0.072	0.076	0.018	-0.065	-0.060	-0.152	-0.038	0.039	-0.032	0.240	0.252	0.215	0.042	**1.000**	0.068
Grain yield/plant	0.112	-0.137	0.117	0.317*	-0.069	0.157	0.221	0.194	0.925**	-0.141	0.209	0.191	0.067	0.068	**1.000**

*Significant at 5% level, **Significant at 1% level

Table 2a: Estimate of direct and indirect effects of 15 different characters on grain yield /plant at genotypic level in parent+F_1 in wheat

Characters	**Days to 50% flowering**	**Plant height (cm)**	**Days to maturity**	**No. of Tillers/ plant**	**Flag leaf area (cm^2)**	**Spike length (cm)**	**No. of spikelets/ spike**	**No. of grains/ spike**	**Biological yield/ plant (g)**	**1000-grain weight(g)**	**Harvest index (%)**	**Protein (%)**	**Phenol color**	**Seed hardness**	**Grain yield/plant**
Days to 50% flowering	**0.0428**	0.0007	-0.0252	-0.0105	0.0005	-0.0033	0.0001	0.0000	-0.0915	-0.0003	0.0054	0.0014	0.0022	-0.0061	-0.084
Plant height (cm)	-0.011	**-0.0026**	0.0087	0.0058	0.0000	-0.0003	-0.0017	0.0004	0.0517	-0.0009	-0.0235	-0.0037	-0.0011	0.0052	0.027
Days to maturity	0.0396	0.0008	**-0.0272**	-0.0106	0.0007	-0.0026	0.0008	0.0001	-0.0849	-0.0001	0.0009	0.0021	0.0029	-0.0048	-0.082
No. of tillers/plant	0.018	0.0006	-0.0116	**-0.0249**	0.0001	-0.0042	0.007	-0.0006	0.3626	0.0009	0.0395	0.0059	0.0016	-0.0028	0.392**
Flag leaf area (cm^2)	-0.0082	0.0000	0.0081	0.0008	**-0.0025**	-0.0006	0.003	-0.0004	-0.012	0.0001	-0.0195	0.0000	-0.0016	0.0002	-0.033

Spike length (cm)	0.0089	-0.0001	-0.0045	-0.0065	-0.0001	**-0.0159**	0.0207	-0.0025	-0.0509	0.0006	0.1087	-0.0001	-0.0034	0.0002	0.055
No. of spikelets/spike	0.0002	0.0002	-0.0008	-0.0066	-0.0003	-0.0126	**0.0262**	-0.0026	0.1133	0.0008	0.041	0.0000	-0.0039	0.0029	0.158
No. of grains/spike	0.0001	0.0002	0.0004	-0.0036	-0.0002	-0.0095	0.016	**-0.0042**	0.0764	0.0013	0.0786	0.0012	-0.0016	0.0004	0.155
Biological yield/plant(g)	-0.0038	-0.0001	0.0023	-0.0088	0.0000	0.0008	0.0029	-0.0003	**1.0234**	0.0001	-0.1443	-0.0006	-0.0013	-0.0004	0.870**
1000-grain weight(g)	-0.0017	0.0003	0.0002	-0.0033	-0.0001	-0.0016	0.0032	-0.0008	0.0097	**0.0066**	0.1168	0.0027	0.0007	0.0054	0.138
Harvest index (%)	0.0005	0.0001	0.0000	-0.0019	0.0001	-0.0034	0.0021	-0.0006	-0.2871	0.0015	**0.5145**	0.0028	-0.0034	0.0001	0.225
Protein (%)	0.0054	0.0008	-0.0051	-0.0129	0.0000	0.0002	-0.0001	-0.0004	-0.0574	0.0016	0.1266	**0.0114**	0.0004	-0.0014	0.069
Phenol color	0.0059	0.0002	-0.0049	-0.0025	0.0002	0.0034	-0.0063	0.0004	-0.0804	0.0003	-0.108	0.0003	**0.016**	-0.0014	-0.177
Seed hardness	-0.0144	-0.0007	0.0072	0.0038	0.0000	-0.0002	0.0041	-0.0001	-0.0222	0.0019	0.0036	-0.0009	-0.0013	**0.0181**	-0.001

R Square = 0.9980 Residual Effect = 0.0443

Table 2b: Estimate of direct and indirect effects of 15 different characters on grain yield /plant at genotypic level in parent+F_2 in wheat

Characters	Days to 50% flowering	Plant height (cm)	Days to maturity	No. of Tillers/ plant	Flag leaf area (cm^2)	Spike length (cm)	No. of spikelets/ spike	No. of grains/ spike	Biological yield/ plant (g)	1000-grain weight(g)	Harvest index (%)	Protein (%)	Phenol color	Seed hardness	Grain yield/plant
Days to 50% flowering	**-0.0005**	0.0003	-0.0026	0.0043	-0.0032	-0.0015	-0.0014	0.001	0.1342	0.0001	-0.0208	0.002	-0.0001	-0.0002	0.112
Plant height (cm)	0.0000	**-0.0048**	0.0003	-0.0048	0.0012	-0.0008	-0.0002	-0.0003	-0.0959	-0.0005	-0.0272	-0.0051	0.0005	0.0002	-0.137
Days to maturity	-0.0005	0.0005	**-0.0031**	0.0034	-0.0029	-0.0003	-0.001	0.0004	0.142	-0.0002	-0.0217	0.0012	-0.0004	0.0000	0.117
No. of tillers/plant	-0.0002	0.0015	-0.0007	**0.0153**	-0.0018	-0.0023	-0.0013	0.0015	0.3115	0.0009	-0.0145	0.0079	-0.001	-0.0001	0.317*
Flag leaf area (cm^2)	0.0002	-0.0007	0.0011	-0.0033	**0.0081**	0.0008	0.001	-0.0003	-0.1573	-0.0004	0.0837	-0.0017	0.0005	-0.0001	-0.069
Spike length (cm)	-0.0001	-0.0005	-0.0001	0.0045	-0.0008	**-0.0078**	-0.0041	0.0031	0.2328	0.0008	-0.0698	0.0004	-0.001	-0.0003	0.157
No. of spikelets/spike	-0.0002	-0.0002	-0.0006	0.0039	-0.0015	-0.0062	**-0.0052**	0.0035	0.289	0.0003	-0.0608	-0.0008	0.0000	-0.0001	0.221
No. of grains/spike	-0.0001	0.0003	-0.0002	0.0039	-0.0004	-0.0041	-0.003	**0.006**	0.1835	0.0007	0.0076	0.0003	-0.0002	0.0001	0.194
Biological yield/plant(g)	-0.0001	0.0005	-0.0004	0.0048	-0.0013	-0.0018	-0.0015	0.0011	**0.9877**	-0.0012	-0.0628	0.0011	-0.0008	-0.0001	0.925**
1000-grain weight(g)	0.0000	0.0004	0.0001	0.0024	-0.0006	-0.0011	-0.0003	0.0007	-0.2028	**0.0057**	0.0491	0.0058	-0.0009	0.0005	-0.141
Harvest index (%)	0.0000	0.0004	0.0002	-0.0006	0.0018	0.0015	0.0009	0.0001	-0.1687	0.0008	**0.3678**	0.0038	0.0008	0.0006	0.209
Protein (%)	-0.0001	0.0016	-0.0003	0.0081	-0.0009	-0.0002	0.0003	0.0001	0.0719	0.0022	0.0929	**0.0150**	-0.0001	0.0005	0.191
Phenol color	0.0000	0.0004	-0.0002	0.0024	-0.0006	-0.0012	0.0000	0.0002	0.1171	0.0008	-0.0462	0.0002	**-0.0064**	0.0001	0.067
Seed hardness	0.0000	-0.0004	-0.0001	-0.001	-0.0005	0.0012	0.0002	0.0002	-0.0313	0.0014	0.0928	0.0032	-0.0003	**0.0023**	0.068

R Square = 0.9966 Residual Effect = 0.0581

Table 2c: Estimate of direct and indirect effects of 15 different characters on grain yield /plant at phenotypic level in parent+F_1 in wheat

Characters	Days to 50% flowering	Plant height (cm)	Days to maturity	No. of Tillers/ plant	Flag leaf area (cm^2)	Spike length (cm)	No. of spikelets/ spike	No. of grains/ spike	Biological yield/ plant (g)	1000-grain weight(g)	Harvest index (%)	Protein (%)	Phenol color	Seed hardness	Grain yield/plant
Days to 50% flowering	**0.096**	0.0011	-0.0678	-0.0203	0.0016	-0.005	0.001	0.0000	-0.1004	-0.0002	0.0073	0.0032	0.003	-0.0076	-0.088
Plant height (cm)	-0.0276	**-0.0038**	0.0261	0.0103	0.0000	-0.0004	-0.0027	0.0008	0.0509	-0.0008	-0.0231	-0.008	-0.0016	0.0061	0.026
Days to maturity	0.0911	0.0014	**-0.0714**	-0.0205	0.0025	-0.0042	0.0022	0.0002	-0.0956	0.0000	-0.0002	0.005	0.004	-0.0062	-0.092
No. of tillers/plant	0.0457	0.0009	-0.0342	**-0.0428**	0.0002	-0.006	0.0118	-0.0013	0.3702	0.0008	0.036	0.0128	0.002	-0.0033	0.393**
Flag leaf area (cm^2)	-0.0201	0.0000	0.0237	0.0013	**-0.0074**	-0.0008	0.0051	-0.0009	-0.0113	0.0001	-0.0191	-0.0001	-0.0022	0.0002	-0.032
Spike length (cm)	0.0221	-0.0001	-0.0138	-0.0118	-0.0003	**-0.0219**	0.0334	-0.0055	-0.053	0.0006	0.111	-0.0003	-0.0046	0.0003	0.056
No. of spikelets/spike	0.0022	0.0002	-0.0037	-0.0122	-0.0009	-0.0176	**0.0414**	-0.0057	0.1224	0.0008	0.0424	0.0001	-0.0055	0.0035	0.167
No. of grains/spike	-0.0004	0.0003	0.0017	-0.0063	-0.0007	-0.0133	0.0258	**-0.0091**	0.0794	0.0012	0.0821	0.0026	-0.0022	0.0005	0.162
Biological yield/plant(g)	-0.0093	-0.0002	0.0066	-0.0153	0.0001	0.0011	0.0049	-0.0007	**1.0336**	0.0001	-0.1431	-0.0014	-0.0018	-0.0005	0.874**

1000-grain weight(g)	-0.004	0.0005	0.0005	-0.0058	-0.0002	-0.0022	0.0053	-0.0018	0.0095	**0.006**	0.1184	0.0058	0.0009	0.0063	0.139
Harvest index (%)	0.0014	0.0002	0.0000	-0.003	0.0003	-0.0048	0.0035	-0.0015	-0.2909	0.0014	**0.5085**	0.0061	-0.0045	0.0002	0.217
Protein (%)	0.0128	0.0013	-0.0148	-0.0227	0.0000	0.0002	0.0001	-0.001	-0.058	0.0014	0.1289	**0.0241**	0.0007	-0.0016	0.072
Phenol color	0.0143	0.0003	-0.0139	-0.0042	0.0008	0.005	-0.0113	0.001	-0.09	0.0003	-0.1118	0.0008	**0.0203**	-0.0017	-0.19
Seed hardness	-0.0347	-0.0011	0.021	0.0068	-0.0001	-0.0003	0.0069	-0.0002	-0.0232	0.0018	0.0039	-0.0019	-0.0016	**0.021**	-0.002

R Square = 0.9963 Residual Effect = 0.0610

Table 2d: Estimate of direct and indirect effects of 15 different characters on grain yield /plant at phenotypic level in parent+F_2 in wheat

Characters	**Days to 50% flowering**	**Plant height (cm)**	**Days to maturity**	**No. of Tillers/ plant**	**Flag leaf area (cm^2)**	**Spike length (cm)**	**No. of spikeles/ spike**	**No. of grains/ spike**	**Biological yield/ plant (g)**	**1000-grain weight(g)**	**Harvest index (%)**	**Protein (%)**	**Phenol color**	**Seed hardness**	**Grain yield/plant**
Days to 50% flowering	**0.0013**	0.0002	-0.0042	0.005	-0.0033	-0.002	-0.0009	0.0008	0.1333	0.0001	-0.0202	0.0019	-0.0001	-0.0001	0.112
Plant height (cm)	-0.0001	**-0.0032**	0.0005	-0.0056	0.0013	-0.0011	-0.0002	-0.0003	-0.0985	-0.0005	-0.0309	-0.0047	0.0004	0.0001	-0.143
Days to maturity	0.0011	0.0003	**-0.0049**	0.0042	-0.0031	-0.0004	-0.0007	0.0003	0.1431	-0.0002	-0.0232	0.0012	-0.0003	0.0000	0.118
No. of tillers/plant	0.0004	0.001	-0.0012	**0.0174**	-0.0018	-0.0029	-0.0008	0.0012	0.3146	0.0009	-0.017	0.0075	-0.0008	-0.0001	0.318*
Flag leaf area (cm^2)	-0.0005	-0.0005	0.0018	-0.0039	**0.0082**	0.001	0.0006	-0.0003	-0.1631	-0.0004	0.0867	-0.0016	0.0004	-0.0001	-0.072
Spike length (cm)	0.0003	-0.0004	-0.0002	0.0053	-0.0008	**-0.0097**	-0.0025	0.0025	0.2427	0.0008	-0.072	0.0004	-0.0009	-0.0002	0.165
No. of spikelets/spike	0.0004	-0.0002	-0.0011	0.0047	-0.0016	-0.0079	**-0.0031**	0.0027	0.3066	0.0003	-0.0644	-0.0008	0.0000	-0.0001	0.236
No. of grains/spike	0.0002	0.0002	-0.0003	0.0046	-0.0004	-0.0051	-0.0017	**0.0047**	0.1908	0.0007	0.0074	0.0002	-0.0001	0.0000	0.201
Biological yield/plant(g)	0.0002	0.0003	-0.0007	0.0056	-0.0014	-0.0024	-0.001	0.0009	**0.9833**	-0.0012	-0.0535	0.001	-0.0006	0.0000	0.931**
1000-grain weight(g)	0.0000	0.0003	0.0002	0.0028	-0.0007	-0.0014	-0.0002	0.0006	-0.2046	**0.0056**	0.0503	0.0053	-0.0007	0.0003	-0.142
Harvest index (%)	-0.0001	0.0003	0.0003	-0.0008	0.002	0.002	0.0006	0.0001	-0.1485	0.0008	**0.3541**	0.0038	0.0007	0.0003	0.215
Protein (%)	0.0002	0.0011	-0.0004	0.0095	-0.0009	-0.0003	0.0002	0.0001	0.0709	0.0022	0.0968	**0.0137**	-0.0001	0.0002	0.193
Phenol color	0.0000	0.0003	-0.0003	0.0028	-0.0006	-0.0018	0.0000	0.0001	0.1168	0.0009	-0.0498	0.0002	**-0.0047**	0.0000	0.064
Seed hardness	-0.0001	-0.0002	-0.0001	-0.0011	-0.0005	0.0015	0.0001	0.0002	-0.0338	0.0014	0.0966	0.0029	-0.0002	**0.0011**	0.068

R Square = 0.9959 Residual Effect = 0.0638

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