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# Correlation and Path Coefficient Analysis in Wheat (*Triticum aestivum* L. em.Thell)

**K. P. Singh*, Vinod Singh, Gaurav Sharma, M. P. Chauhan, Tejasvi Singh and R. D. S. Yadav**

*Department of Genetics and Plant Breeding, Acharya Narendra Deva University of Agriculture and technology, Kumarganj, Ayodhya, Uttar Pradesh, India*

**Corresponding author*

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**A B S T R A C T**

The present study was carried out during *Rabi* seasons of 2017-18 & 2018-19 at Main Experimental Station, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The experimental materials comprised of twenty genetically diverse varieties/strains and their 105 crosses. The 26 parents were involved in a crossing programme to develop a line x tester set (21 lines + 5 testers + 3 checks) during Rabi season of 2017-18in Randomized Block Design. The experimental materials were evaluated in two conditions i.e. timely sown ($E_1$) and late sown ($E_2$) condition for twelve quantitative characters. The harvest index (0.843), tiller per plant (0.154), spike length (0.146) showed highly positive phenotypic correlation with in $E_1$ for grain yield per plant, whail grain yield per plant exhibited highly positive phenotypic correlation with harvest index (0.687), test weight (0.111) and spikelet per spike (0.101) in $E_2$. The highest positive direct effect on grain yield per plant was exerted vai harvest index (1.340), plant height (0.005), penduncle length (0.003). Whereas $E_2$ showed direct positive effect on grain yield per plant by harvest index (1.624), biological yield (1.179), and flag leaf area (0.016).The highest positive indirect effect on grain yield was exerted by days to maturity (0.141) via biological yield per plant followed by days to 50% flowering (0.092) via biological yield per plant, test weight (0.040) via biological yield per plant, tiller per plant and spike length (0.005) via biological yield per plant and flag leaf area (0.003) via biological yield per plant in $E_1$. While in $E_2$ highest positive indirect effect on grain yield showed by plant height (0.220) via biological yield per plant followed by days to maturity (0.151), tiller per plant (0.053) peduncle length (0.044), test weight (0.033).

## Introduction

Wheat, (*Triticum aestivum* L. *em.* Thell) the world's largest cereal crop which belongs to Graminae (Poaceae) family of the genus *Triticum*. It has been described as the 'King of cereals' because of the acreage it occupies, high productivity and the prominent position in the international food grain trade. Wheat is consumed in a variety of ways such as bread chapatti, porridge, flour, suji etc.

The term "Wheat" is derived from many different locations, specifically from English,

German and Welsh language. Wheat is most commonly defined by all cultures as "that which is white" due to its physical characteristics of light colored crops.

In India, during 2019-20 Rabi season, wheat has been cultivated in 30.55 million hectares constituting 24.34 per cent of the total crop acreage. Indian wheat production in 2019-20 has made another landmark achievement by producing 107.18 mt with an average national productivity of 3508 kg/ha. During the past year production was also more than 100 million tonnes (103.60 million tonnes) and the current year production has witnessed a change of 3.58 million tonnes (+3.46%). The positive growth in production is attributed to the increased area by 4.21 per cent despite a fall in the crop yield marginally by - 0.72 percent. Increase in the support price by `85 per quintal in comparison to the recent past year and announced as `1925 per quintal of wheat, might have had a positive impact on the crop acreage (+1.24 million hectares). The crop area and productivity have increased in a majority of the states is a main reason behind the landmark production. States like Madhya Pradesh, Maharashtra, Gujarat and Rajasthan have shown a significant increase in the crop area over the past year have resulted in a major quantum jump in overall wheat production Anonymous (2019).

Among the wheat producing states, Uttar Pradesh registered a significant level of crop output estimated at 32.09 million tonnes (30%), followed by Madhya Pradesh (18.58 million tonnes: 17%), Punjab (18.21 million tonnes: 17%), Haryana (12.07 million tonnes: 11%), Rajasthan (10.57 million tonnes: 10%) and Bihar (6.55 million tonnes: 6%). The aforementioned six states hold a share of about 92 per cent in total wheat production. With the exception of Chhatisgarh, Haryana, Odisha, Punjab, Telangana and Uttar Pradesh, the rest of the states registered an increase in production during 2019-20 relative to 2018-19. Overall production from all these states has declined by 1.23 million tonnes owing to the fall in yield levels and/or acreage. The highest fall was noticed in Uttar Pradesh (-0.65 million tonnes: -1.99%). The increase in wheat production was maximum in the case of Madhya Pradesh (+2.06 million tonnes: +12.48%), followed by Gujarat (+0.85 million tonnes: +35.46%) and Maharashtra (+0.83 million tonnes: 66.20%). In percentage terms, it was highest for West Bengal (72.53%: 0.25 million tonnes), Anonymous (2019)

## Materials and Methods

The present investigation entitled "Studies on combining ability and heterosis for yield and its components under sodic soil in bread wheat (*Triticum aestivum* L. em. Thell.)" was conducted in RBD in three replications at Main Experiment Station of AcharyaNarendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during *Rabi*, 2017-19.

Geographically, experimental site is located between $24^0$ 47´ and $26^0$ 56´ N latitude, $82^0$ 12´ and $83^0$ 98´ E longitude and at an altitude of 113 m above mean sea level. This area falls in sub-tropical climatic zone. The soil type is sandy loam. The annual rainfall is about 1270 mm. The climate of district Ayodhya is semi-arid with hot summer and cold winter.

The experimental materials of the study comprised of 134 treatments of wheat. These materials included 105 $F_1$'s, 26 parental lines (21 females + 5 males) and three standard varieties. Twelve lines were crossed with 5 testers following Line x Tester mating design during *rabi* season 2017-18 at Main Experiment Station **(**MES), AcharyaNarendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.).

Observations on the twelve characters were recorded on 5 randomly selected plants in each replication for following characters *viz.* days to 50% flowering, days to maturity, plant height (cm), tillers per plant, spike length (cm), flag leaf area ($cm^2$), peduncle length (cm), 1000-grain weight (g), biological yield per plant (g), grain yield per plant (g), harvest index (%)and spikelets/spike (no.) except days to 50% flowering and days to maturity which is on plot basis.

## Material used in experiment

Twenty one lines NW-1067, NW-4018, NW-1012, PBW-17, PBW-154, PBW-373, PBW-343, DBW-39, DBW-14, DBW-22, HD-2733, HD-2824, KRL-392, KRL-20, KRL-391, KRL-393, KRL-99, KRL-213, HI-1563, GW-366 and HUW-234) with 5 testers (KRL-1-4, KRL-19, KRL-3-4, NW-2036 and HD-2967 with five tester KRL-1-4, KRL-19, KRL-3-4, NW-2036 and HD-2967 and three check namely, UP-2338, PBW-550 and NW-5054.

## Data analysis

The data thus recorded were subjected to statistical and biometrical analysis as detailed as follows: Correlation coefficient analysis as calculated by Al-Jibouri *et al.*, (1958) to test the significant correlation between the traits. Path coefficient analysis was performed to assess direct and indirect effect of the measured traits on grain yield according to the technique outlined by Dewey and Lu (1959).

## Results and Discussion

The genetic architecture of grain yield in as well as other crops is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with one another. Therefore, selection for yield *per se* alone would not matter much as such unless accompanied by the selection for various component characters responsible for conditioning Thus, identification of important components and information about their association with yield and with each other are very useful for developing efficient breeding strategy for evolving high yielding varieties/hybrids. The correlation coefficient is the measure of degree of symmetrical association between two variables or characters which helps us in understanding the nature and magnitude of association among yield and yield components. In the present investigation, phenotypic and genotypic correlation coefficients were computed among 12 characters (Table 1 and 2) in timely ($E_1$) and late ($E_2$) conditions.

## Path coefficient analysis

Path coefficient analysis is a tool to partition the observed correlation coefficient into direct and indirect effects of yield components on seed yield. Path analysis provides clearer picture of character associations for formulating efficient Selection strategy. The path coefficient analysis using genotypic as well as phenotypic correlation coefficient estimated in $E_1$ and $E_2$ conditions were carried out to asses direct and indirect effects of twelve characters on the expression of grain yield per plant.

The highest positive direct effect on grain yield per plant were exerted by harvest index (1.340), plant height (0.005), penduncle length (0.003) and negative direct effect on grain yield per plant were exerted by test weight (-0.005) and spike length (-0.004) in $E_1$; whereas $E_2$ showed direct effect on grain yield per plant by harvest index (1.624), biological yield (1.179), and flag leaf area (0.016). While negative by tiller per plant (-0.020), days to 50% lowering (-0.016) and plant height (-0.014) in $E_2$.

**Table.1** Estimation of direct and indirect effect of 12 characters on grain yield/ plant at phenotypic and genotypic level under timely sown ($E_1$) condition in wheat

| | | Day to 50% flowering | Flag leaf area $(cm)^2$ | Days to maturity | Plant height (cm) | Tillers/ plant | Spike length (cm) | Peduncle length (cm) | Biological yield/ Plant (gm) | Test weight (gm) | Harvest index (%) | Spikelets/ spike | Grain yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days to 50% flowering** | P | **0.00190** | 0.00040 | 0.00020 | 0.00000 | 0.00000 | 0.00030 | 0.00030 | 0.09280 | 0.00010 | -0.24490 | -0.00010 | -0.149** |
| | G | **0.016** | -0.001 | 0.001 | 0.000 | -0.007 | 0.000 | -0.002 | 0.158 | 0.000 | -0.376 | -0.001 | -0.213** |
| **Flag leaf area ($cm^2$)** | P | 0.00030 | **0.00250** | 0.00000 | -0.00030 | 0.00000 | -0.00010 | -0.00020 | 0.00310 | 0.00060 | -0.06260 | -0.00010 | -0.057 |
| | G | 0.005 | **-0.004** | 0.000 | -0.001 | 0.002 | 0.000 | 0.001 | -0.008 | -0.001 | -0.034 | 0.000 | -0.040 |
| **Days to maturity** | P | 0.00080 | 0.00000 | **0.00050** | -0.00020 | 0.00000 | 0.00110 | 0.00070 | 0.14170 | -0.00100 | -0.36270 | 0.00010 | -0.219** |
| | G | 0.007 | 0.000 | **0.002** | 0.000 | -0.009 | 0.001 | -0.006 | 0.258 | 0.001 | -0.622 | 0.001 | -0.367** |
| **Plant height (cm)** | P | 0.00000 | -0.00010 | 0.00000 | **0.00590** | 0.00000 | 0.00010 | 0.00030 | -0.03980 | -0.00060 | 0.09560 | -0.00010 | 0.061 |
| | G | 0.000 | 0.000 | 0.000 | **0.007** | -0.001 | 0.000 | -0.002 | -0.064 | 0.001 | 0.141 | 0.000 | 0.083 |
| **Tillers/plant** | P | -0.00010 | 0.00010 | 0.00000 | -0.00020 | **0.00050** | -0.00010 | 0.00030 | 0.00580 | 0.00080 | 0.14690 | 0.00010 | 0.154** |
| | G | -0.003 | 0.000 | -0.001 | 0.000 | **0.034** | 0.000 | -0.006 | -0.045 | -0.002 | 0.488 | 0.001 | 0.465** |
| **Spike length (cm)** | P | -0.00010 | 0.00010 | -0.00010 | -0.00020 | 0.00000 | **-0.00470** | -0.00020 | 0.00580 | 0.00080 | 0.14420 | 0.00000 | 0.146** |
| | G | -0.001 | 0.000 | -0.001 | 0.000 | 0.001 | **-0.003** | 0.001 | 0.033 | -0.001 | 0.211 | 0.000 | 0.239** |
| **Peduncle length (cm)** | P | 0.00010 | -0.00010 | 0.00010 | 0.00040 | 0.00000 | 0.00020 | **0.00390** | -0.05410 | -0.00090 | 0.03300 | 0.00070 | -0.017 |
| | G | 0.002 | 0.000 | 0.001 | 0.001 | 0.013 | 0.000 | **-0.017** | -0.074 | 0.001 | 0.043 | 0.005 | -0.025 |
| **Biological yield/plant (g)** | P | 0.00020 | 0.00000 | 0.00010 | -0.00030 | 0.00000 | 0.00000 | -0.00030 | **0.73110** | -0.00030 | -0.91360 | -0.00010 | -0.183** |
| | G | 0.003 | 0.000 | 0.001 | -0.001 | -0.002 | 0.000 | 0.002 | **0.741** | 0.000 | -1.007 | -0.001 | -0.264** |
| **Test weight (g)** | P | 0.00000 | -0.00030 | 0.00010 | 0.00070 | -0.00010 | 0.00070 | 0.00070 | 0.04090 | **-0.00530** | -0.27320 | 0.00030 | -0.236** |
| | G | 0.000 | 0.001 | 0.001 | 0.001 | -0.013 | 0.001 | -0.003 | 0.049 | **0.005** | -0.321 | 0.002 | -0.279** |
| **Harvest index (%)** | P | -0.00040 | -0.00010 | -0.00010 | 0.00040 | 0.00000 | -0.00050 | 0.00010 | -0.49810 | 0.00110 | **1.34090** | -0.00010 | 0.843** |
| | G | -0.004 | 0.000 | -0.001 | 0.001 | 0.012 | -0.001 | -0.001 | -0.538 | -0.001 | **1.387** | -0.001 | 0.854** |
| **Spikelets/Spike** | P | -0.00010 | -0.00010 | 0.00000 | -0.00010 | 0.00000 | 0.00000 | 0.00100 | -0.01850 | -0.00060 | -0.06890 | **0.00280** | -0.084 |
| | G | -0.001 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | -0.008 | -0.047 | 0.001 | -0.076 | **0.011** | -0.116* |

*, ** significant at 5 and 1 per cent probability levels, respectively

**Table.2** Estimates of direct and indirect effect of 12 characters on grain yield per plant at phenotypic and genotypic level under late sown ($E_2$) condition in wheat

| | | Days to 50% flowering | Flag leaf area ($cm^2$) | Days to maturity | Plant height (cm) | Tillers/ plant | Spike length (cm) | Peduncle length (cm) | Biological yield/ plant (g) | Test weight (g) | Harvest index (%) | Spikelets/spike | Grain yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days to 50% flowering** | P | **-0.0162** | -0.0018 | 0.0000 | -0.0019 | -0.0004 | -0.0003 | -0.0004 | -0.2042 | 0.0002 | 0.3062 | -0.0005 | 0.081 |
| | G | **-0.134** | 0.048 | 0.022 | 0.028 | 0.014 | 0.028 | -0.079 | -0.594 | -0.003 | 1.008 | -0.094 | 0.244** |
| **Flag leaf area ($cm^2$)** | P | 0.0018 | **0.0164** | 0.0000 | 0.0005 | 0.0012 | 0.0001 | 0.0001 | -0.1002 | 0.0002 | 0.1463 | 0.0004 | 0.067 |
| | G | 0.040 | **-0.158** | 0.018 | -0.023 | -0.052 | -0.001 | 0.124 | -0.324 | 0.030 | 0.458 | 0.006 | 0.117* |
| **Days to maturity** | P | 0.0011 | 0.0002 | **0.0005** | -0.0007 | -0.0008 | -0.0003 | 0.0000 | 0.1512 | 0.0002 | -0.2273 | -0.0006 | -0.076 |
| | G | 0.020 | 0.019 | **-0.149** | 0.054 | 0.036 | 0.007 | 0.045 | 0.413 | -0.001 | -0.673 | 0.065 | -0.163** |
| **Plant height (cm)** | P | -0.0021 | -0.0006 | 0.0000 | **-0.0149** | 0.0005 | 0.0000 | -0.0003 | 0.2209 | 0.0000 | -0.1299 | 0.0000 | 0.074 |
| | G | -0.016 | 0.016 | -0.035 | **0.234** | 0.006 | 0.014 | -0.123 | 0.467 | -0.003 | -0.371 | -0.112 | 0.076 |
| **Tillers/plant** | P | -0.0003 | -0.0009 | 0.0000 | 0.0003 | **-0.0207** | 0.0002 | -0.0005 | 0.0533 | 0.0000 | -0.0491 | -0.0004 | -0.018 |
| | G | -0.011 | 0.049 | -0.033 | 0.008 | **0.166** | -0.044 | -0.136 | -0.205 | -0.047 | 0.161 | 0.005 | -0.086 |
| **Spike length (cm)** | P | 0.0006 | 0.0002 | 0.0000 | 0.0001 | -0.0005 | **0.0071** | -0.0008 | -0.0884 | 0.0003 | 0.1056 | 0.0007 | 0.025 |
| | G | 0.028 | -0.002 | 0.008 | -0.024 | 0.054 | **-0.134** | -0.004 | -0.222 | 0.027 | 0.257 | 0.039 | 0.027 |
| **Peduncle length (cm)** | P | -0.0016 | -0.0004 | 0.0000 | -0.0010 | -0.0025 | 0.0014 | **-0.0040** | 0.0441 | -0.0006 | 0.0365 | -0.0004 | 0.071 |
| | G | -0.043 | 0.079 | 0.027 | 0.117 | 0.091 | -0.002 | **-0.247** | -0.362 | -0.019 | 0.924 | -0.160 | 0.404** |
| **Biological yield/plant (g)** | P | 0.0028 | -0.0014 | 0.0001 | -0.0028 | -0.0009 | -0.0005 | -0.0001 | **1.1792** | -0.0002 | -1.2907 | 0.0007 | -0.114* |
| | G | 0.062 | 0.040 | -0.048 | 0.086 | -0.027 | 0.024 | 0.071 | **1.270** | -0.027 | -1.652 | 0.006 | -0.196** |
| **Test weight (g)** | P | 0.0005 | -0.0004 | 0.0000 | -0.0001 | 0.0001 | -0.0003 | -0.0003 | 0.0338 | **-0.0075** | 0.0849 | 0.0001 | 0.111* |
| | G | -0.002 | 0.032 | -0.001 | 0.005 | 0.053 | 0.024 | -0.032 | 0.237 | **-0.145** | 0.129 | -0.022 | 0.278** |
| **Harvest index (%)** | P | -0.0031 | 0.0015 | -0.0001 | 0.0012 | 0.0006 | 0.0005 | -0.0001 | -0.9370 | -0.0004 | **1.6243** | -0.0010 | 0.687** |
| | G | -0.066 | -0.036 | 0.049 | -0.043 | 0.013 | -0.017 | -0.112 | -1.030 | -0.009 | **2.036** | -0.057 | 0.729** |
| **Spikelets/spike** | P | -0.0013 | -0.0010 | 0.0000 | 0.0000 | -0.0011 | -0.0007 | -0.0003 | -0.1170 | 0.0001 | 0.2289 | **-0.0067** | 0.101* |
| | G | -0.111 | 0.008 | 0.086 | 0.231 | -0.007 | 0.047 | -0.351 | -0.064 | -0.028 | 1.025 | **-0.113** | 0.724** |

*, ** significant at 5 and 1 per cent probability levels, respectively

**Table.3** Estimates of phenotypic and genotypic correlation coefficient between 12 characters under timely sown ($E_1$) condition in wheat

| Character | | Day to 50% flowering | Flag leaf area (cm)² | Days to maturity | Plant height (cm) | Tillers/ plant | Spike length (cm) | Peduncle length (cm) | Biological yield/ plant (gm) | Test weight (gm) | Harvest index (%) | Spikelets/spike | Grain yield/ plant (gm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days to 50% flowering** | **P** | **1.000** | 0.159** | 0.396** | -0.001 | -0.032 | -0.072 | 0.072 | 0.1 | -0.022 | -0.183** | -0.050 | -0.149** |
| | **G** | **1.000** | 0.297** | 0.422** | -0.003 | -0.213** | -0.088 | 0.139** | 0.213** | -0.017 | -0.271** | -0.063 | -0.213** |
| **Flag leaf area (cm²)** | **P** | | **1.000** | -0.011 | -0.047 | 0.027 | 0.030 | -0.042 | 0.004 | -0.116* | -0.047 | -0.032 | -0.057 |
| | **G** | | **1.000** | -0.038 | -0.082 | 0.053 | 0.043 | -0.050 | -0.011 | -0.184** | -0.024 | -0.015 | -0.040 |
| **Days to maturity** | **P** | | | **1.000** | -0.034 | -0.046 | -0.224** | 0.191** | 0.194** | 0.182** | -0.271** | 0.041 | -0.219** |
| | **G** | | | **1.000** | -0.053 | -0.253** | -0.338** | 0.327** | 0.348** | 0.274** | -0.449** | 0.100* | -0.367** |
| **Plant height (cm)** | **P** | | | | **1.000** | -0.033 | -0.026 | 0.067 | -0.054 | 0.115* | 0.071 | -0.019 | 0.061 |
| | **G** | | | | **1.000** | -0.019 | -0.063 | 0.093 | -0.086 | 0.126* | 0.102* | 0.008 | 0.083 |
| **Tillers/plant** | **P** | | | | | **1.000** | 0.011 | 0.076 | 0.008 | -0.148** | 0.110* | 0.051 | 0.154** |
| | **G** | | | | | **1.000** | 0.028 | 0.366** | -0.061 | -0.392** | 0.352** | 0.061 | 0.465** |
| **Spike length (cm)** | **P** | | | | | | **1.000** | -0.046 | 0.008 | -0.142** | 0.108* | -0.005 | 0.146** |
| | **G** | | | | | | **1.000** | -0.058 | 0.044 | -0.181** | 0.152** | -0.031 | 0.239** |
| **Peduncle length (cm)** | **P** | | | | | | | **1.000** | -0.074 | 0.177** | 0.025 | 0.253** | -0.017 |
| | **G** | | | | | | | **1.000** | -0.099* | 0.205** | 0.031 | 0.454** | -0.025 |
| **Biological yield/plant (g)** | **P** | | | | | | | | **1.000** | 0.056 | -0.681** | -0.025 | -0.183** |
| | **G** | | | | | | | | **1.000** | 0.066 | -0.726** | -0.063 | -0.264** |
| **Test weight (g)** | **P** | | | | | | | | | **1.000** | -0.204** | 0.121* | -0.236** |
| | **G** | | | | | | | | | **1.000** | -0.231** | 0.206** | -0.279** |
| **Harvest index (%)** | **P** | | | | | | | | | | **1.000** | -0.051 | 0.843** |
| | **G** | | | | | | | | | | **1.000** | -0.055 | 0.854** |
| **Spikelets/Spike** | **P** | | | | | | | | | | | **1.000** | -0.084 |
| | **G** | | | | | | | | | | | **1.000** | -0.116* |

*, ** significant at 5 and 1 per cent probability levels, respectively

**Table.4** Estimates of phenotypic and genotypic correlation coefficient between 12 characters under late sown condition in wheat

| Character | | Day to 50% flowering | Flag leaf area $(cm)^2$ | Days to maturity | Plant height (cm) | Tillers/plant | Spike length (cm) | Peduncle length (cm) | Biological yield/ plant (gm) | Test weight (gm) | Harvest index (%) | Spikelets /spike | Grain yield/ plant (gm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days to 50% flowering** | P | **1.000** | -0.108* | -0.066 | 0.128* | 0.020 | -0.037 | 0.097 | -0.173** | -0.033 | 0.188** | 0.079 | 0.081 |
| | G | **1.000** | -0.301** | -0.151** | 0.118* | 0.083 | -0.209** | 0.321** | -0.468** | 0.018 | 0.495** | 0.828** | 0.244** |
| **Flag leaf area ($cm^2$)** | P | | **1.000** | 0.015 | -0.034 | -0.057 | 0.012 | -0.025 | -0.085 | -0.025 | 0.090 | -0.064 | 0.067 |
| | G | | **1.000** | -0.121* | -0.100* | -0.313** | 0.011 | -0.500** | -0.255** | -0.205** | 0.225** | -0.053 | 0.117* |
| **Days to maturity** | P | | | **1.000** | 0.049 | 0.039 | -0.036 | 0.011 | 0.128* | -0.023 | -0.140** | 0.090 | -0.076 |
| | G | | | **1.000** | 0.233** | 0.219** | -0.052 | -0.181** | 0.325** | 0.005 | -0.331** | -0.577** | -0.163** |
| **Plant height (cm)** | P | | | | **1.000** | -0.022 | -0.004 | 0.065 | 0.187** | 0.004 | -0.080 | -0.002 | 0.074 |
| | G | | | | **1.000** | 0.036 | -0.101* | 0.499** | 0.367** | 0.023 | -0.182** | 0.990** | 0.076 |
| **Tillers/plant** | P | | | | | **1.000** | 0.026 | 0.123* | 0.045 | -0.006 | -0.030 | 0.053 | -0.018 |
| | G | | | | | **1.000** | 0.329** | 0.549** | -0.162** | 0.321** | 0.079 | -0.042 | -0.086 |
| **Spike length (cm)** | P | | | | | | **1.000** | 0.197** | -0.075 | -0.040 | 0.065 | -0.103* | 0.025 |
| | G | | | | | | **1.000** | 0.017 | -0.175** | -0.182** | 0.126* | -0.348** | 0.027 |
| **Peduncle length (cm)** | P | | | | | | | **1.000** | 0.037 | 0.084 | 0.022 | 0.063 | 0.071 |
| | G | | | | | | | **1.000** | -0.285** | 0.131** | 0.454** | 1.418** | 0.404** |
| **Biological yield/plant (g)** | P | | | | | | | | **1.000** | 0.029 | -0.795** | -0.099* | -0.114* |
| | G | | | | | | | | **1.000** | 0.186** | -0.811** | -0.051 | -0.196** |
| **Test weight (g)** | P | | | | | | | | | **1.000** | 0.052 | -0.011 | 0.111* |
| | G | | | | | | | | | **1.000** | 0.063 | 0.194** | 0.278** |
| **Harvest index (%)** | P | | | | | | | | | | **1.000** | 0.141** | 0.687** |
| | G | | | | | | | | | | **1.000** | 0.504** | 0.729** |
| **Spikelets/Spike** | P | | | | | | | | | | | **1.000** | 0.101* |
| | G | | | | | | | | | | | **1.000** | 0.724** |

*, ** significant at 5 and 1 per cent probability levels, respectively

Highest positive indirect effect on grain yield was exerted by days to maturity (0.141) via biological yield per plant followed by days to 50% flowering (0.092) via biological yield per plant, test weight (0.040) via biological yield per plant, tiller per plant and spike length (0.005) via biological yield per plant and flag leaf area (0.003) via biological yield per plant in $E_1$. Besides, $E_1$ also have the negative indirect effect on grain yield which was exerted by harvest index (-0.498) via biological yield per plant followed by peduncle length (-0.054), plant height (-0.039) and spikelets per spike (-0.018) via biological yield per plant. Positive and highest indirect effect on grain yield was exerted by plant height (0.220) via biological yield per plant followed by days to maturity (0.151), tiller per plant (0.053) peduncle length (0.044), test weight (0.033) and negative indirect effect on grain yield were exerted by harvest index (-0.937) via biological yield per plant followed by days to 50% flowering (-0.204), flag leaf area (-0.1002) and by spike length (-0.088) via biological yield per plant in $E_2$ (Table.1 and 2) the indirect effects of remaining characters were too low to be considered as important and the above mentioned characters emerged as most important direct yield contributors on which emphasis should be given during simultaneous selection aimed at improving grain yield in wheat. These characters have also been identified as major direct contributors towards seed yield by Singh, Bhuri and Upadhyay, P.K. (2013), Ayccek and Yldrm (2006), Sherif *et al.,* (2005), Payal *et al.,* (2007), Dharmendra and Singh (2010), Tripathi *et al.,* (2011), El-Mohsen *et al.,* (2012) and Bhutto *et al., (*2015).

## Correlation coefficient

Correlation study of twelve traits revealed that besides grain yield traits are also correlated with each other. Thus, selection practiced for improving these traits individually or simultaneously would bring improvement in other due to correlated response. This suggested that selection would be quite efficient in improving yield and yield components in wheat (Table.3 and 4).

Grain yield per plant exhibited highly positive phenotypic correlation with harvest index (0.843), tiller per plant (0.154) and spike length (0.146) in $E_1$ and negative correlation for the $E_1$ with test weight (-0.236), days to maturity (-0.219), biological yield per plant (-0.183) and days to 50% flowering (-0.149), while grain yield per plant exhibited highly positive phenotypic correlation with harvest index (0.687), test weight (0.111) and spikelet per spike (0.101) in $E_2$. In $E_2$ also showed negative phenotypic correlation with biological yield per plant (-0.114).Days to maturity showed positive correlation with days to 50% flowering (0.396) in $E_1$ and remaining traits were non-significant in $E_1$ as well as in $E_2$.

Flag leaf area showed highly positive correlation with days to 50% flowering (0.159) in $E_1$. whereas for $E_2$ showed negative association with days to 50% flowering (-0.108), whereas plant height showed non-significant correlation with in $E_1$, whereas, in $E_2$ days to 50% flowering (0.128), and rest of the characters either very less or non-significant, whereas tillers per plant showed non-significant correlation for all the characters in $E_1$as well as for $E_2$ and spike length showed negative association with days to maturity (-0.224) and rest of all the characters were non-significant in $E_1$, while $E_2$ possessed non-significant association.

Peduncle length was positively correlated with days to maturity (0.191), while remaining traits were of non-significant in $E_1$, On the other hand, peduncle length showed positively correlation with spike length

(0.197) and tiller per plant (0.123);remaining traits were non-significant in $E_2$.

Biological yield per plant showed positively association with days to maturity (0.194) and days to 50% flowering (0.127) and remaining traits were non-significant in $E_1$. while Biological yield per plant showed positive association with plant height (0.187), days to maturity (0.128) and negative correlated with days to 50% flowering (-0.173) in $E_2$.

Test weight showed positively associated with days to maturity (0.182), penduncle length (0.177), plant height (0.115) and negatively correlated with tiller per plant (-0.148), spike length (-0.142), flag leaf area (-0.116) in $E_2$ it showed non-significant correlation with all characters, while harvest index showed highly positive significant correlation with tillers per plant (0.110), spike length (0.108) and negatively correlated with biological yield per plant (-0.681), days to maturity (-0.271), test weight (-0.204) and days to maturity (-0.183) in $E_1$. While in $E_2$ showed positive correlation with days to 50% flowering (0.188), $E_2$ negative correlation with biological yield per plant (-0.795), days to maturity (-0.140).

Spikelets per spikes content showed highly significant correlation with peduncle length (0.253), test weight (0.121) in $E_1$. While in $E_2$ it was positively correlated with harvest index (0.141) and negatively associated with spike length (-0.103), biological yield (-0.099) and same study have also been reported by Prasad *et al.*, (2006), Payal *et al.*, (2007), Yousaf *et al.*, (2008), Nagireddy and Jyothula (2009), El-Mohsen *et al.*, (2012), Bhutto *et al.*, (2015).

In conclusions the present study shows that Grain yield per plant exhibited highly positive phenotypic correlation with harvest index, test weight and spikelet per spike in $E_2$ and harvest index, tiller per plant, spike length showed highly positive phenotypic correlation with in $E_1$ for grain yield. The highest positive direct effect on grain yield per plant were exerted by harvest index, plant height, penduncle length, whereas $E_1$ showed direct positive effect on grain yield per plant by harvest index, biological yield and flag leaf area. Hence, These characters should be given due consideration during selection for yield improvement of wheat.

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