INTRODUCTION

Wheat (Triticum aestivum L. em. Thell.) is a self-pollinated crop of the member of Poaceae family and one of the most leading cereal of many countries of the world including India. It is the most important food crop of India and is a main source of protein and energy. In India, wheat is the second most important food crop after rice both in terms of area and production. It has been described as the ‘King of cereals’ because of the acreage it occupies, high productivity and the prominent position it holds in the international food grain trade. Globally, demand for wheat by the year 2020 is forecasted around 950 million tonnes to meet future demands imposed by population growth. This target will be achieved only, if global wheat production is increased by 2.5% per annum (Singh et al., 2011). Wheat is a unique gift of nature to the mankind as it can be moulded into innumerable products like chapatis, breads, cakes, biscuits, pasta and many hot and ready-to-eat breakfast foods. Wheat grain contains starch (60-68%), protein (6-21%), fat (1.5-2.0%), cellulose (2.0-2.5%), minerals (1.8%) and vitamins (Das, 2008). The uniqueness of wheat in contrast to other cereals is that wheat contains gluten protein which enables leavened dough to rise by forming minute gas cells and this property enables bakers to produce light breads. The record production in the country during last few years has enabled India to attain the position of being second largest producer of the wheat in the world (DWR Vision 2030). The knowledge of patterns of genetic variation of a crop species in any given region or country is very important for planning future germplasm collection missions and for efficient utilization of collected germplasm in crop improvement programmes (Nagi et al.2013). Understanding of interrelationship between component characters helps in determining which character to select when improvement of the related complex character is desired. The correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for the improvement in associated complex character–yield (Sokoto et al., 2012; Mohammadi et al., 2012). Simple correlation is partitioned into phenotypic (that can be directly observed), genotypic (inherent association between characters) and environmental (environmental deviation together with nonadditive genetic variation) components. The knowledge of association among the yield and yield contributing characters would be of great help in constructing a suitable plant type and in planning breeding programme. Grain yield, being a complex trait, depends upon component variables and their interaction. Degree and direction of relationship between two or more variables lead to estimation of correlation. Correlation studies provide better understanding of yield component which helps the plant breeder during selection (Robinson et al., 1951 and Johnson et al., 1955). However, the correlation coefficient does not give any indication about comparative magnitude of contribution made by various component characters. Therefore, genotypic path coefficient analysis was carried out to find the direct and indirect effects of yield components and their correlation with grain yield per plant.

MATERIAL AND METHOD

Fifty genotypes of bread wheat were sown in a Randomized Block Design (RBD) with three replications during rabi 2014. Each genotype was accommodated in a single row of 2.5 m length with a
spacing of 22.5 cm between rows. The experiment was surrounded by two guard rows to avoid damage and border effects. Other recommended agronomical practices in vogue were followed for reaping good crop. The observations were recorded on 14 quantitative characters viz., days to 50% flowering, grain filling period, days to maturity, plant height, number of effective tillers per plant, length of main spike, peduncle length of main spike, number of spikelet per main spike, number of grains per main spike, grain weight per main spike, 1000 grain weight, grain yield per plant, biological yield per plant, harvest index. Five randomly selected competitive plants in each row of each replication for all the characters were recorded for all the traits under study except of days to 50 per cent flowering, grain filling period and days to maturity which were recorded on plot basis. The data subjected to different statistical analysis viz., Phenotypic and genotypic correlation coefficients of all the characters were worked-out as per Al-Jibouri et al. (1958) and path coefficient analysis was carried-out as per the method suggested by Dewey and Lu (1959).

RESULT AND DISCUSSION

Analysis of variance revealed that highly significant differences among the genotypes were observed for all the traits. Which indicating the presence of good amount of genetic variability among the material studied. The breeder is always concerned for the selection of superior genotype on the basis of phenotypic expression. However, for the quantitative characters, genotypes are influenced by environment, thereby effecting the phenotypic expression. Information regarding the nature and extent of association of morphological character would be helpful in developing suitable plant type, in addition to the improvement of yield a complex character for which direct selection is not effective.

The genotypic correlations were higher than the phenotypic correlation for most of the character studied that indicating least environmental effects on the expression of the traits (Table 1).

**Grain yield per plant (g)**

Grain yield per plant was found to be significantly and positively correlated with biological yield per plant, grain weight per main spike, 1000 grain weight and number of grains per main spike at both the genotypic and phenotypic levels. The positive genotypic association have been reported between grain yield per plant and biological yield per plant (Yadav et al., 2009 and Gelalcha and Hanchinal, 2013); grain weight per main spike (Kumar et al., 2009b); 1000 grain weight (Kumar et al., 2013a) and number of grains per main spike (Gelalcha and Hanchina, 2013). The grain yield per plant with positive correlation at phenotypic level with number of effective tillers per plant has been reported by Singh et al., 2012 and Gelalcha and Hanchinal, 2013.

**Days to 50% flowering**

The days to 50% flowering showed negative and significant correlation both at genotypic and phenotypic levels with harvest index, grain filling period and grain weight per main spike. This character showed positive and significant correlation both at genotypic and phenotypic levels with days to maturity (Kumar et al., 2013b), plant height and number of spikelet per main spike (Sharma et al., 2006). Whereas remaining characters were non-significant at both the levels.

**Grain Filling Period**

Significant and negative correlation both at genotypic and phenotypic levels for this trait with grain filling period have been also reported by Munir et al., 2007, 1000 grain weight by Singh et al., 2003 and Yadav et al., 2006a and grain weight per main spike by Yadav et al., 2006a. The character grain filling period exhibited positive and significant correlation at genotypic and phenotypic levels with peduncle length of main spike, which have been also reported by Sharma et al., 2006 and Khan et al., 2010.

**Days to maturity**

The days to maturity showed negative and significant correlation at genotypic level with grain weight per main spike and harvest index, while positive and highly significant at both genotypic and phenotypic levels with plant height and number of spikelet per main spike. The association of days to maturity was positive and highly significant with harvest index at phenotypic level by Sharma et al., 2006 and Khan et al., 2010.

**Plant height (cm)**

The plant height exhibited significant but negative correlation for harvest index at genotypic level, while positive and significant association with length of main spike, peduncle length of main spike, number of spikelet per main spike and biological yield per plant both at genotypic and phenotypic levels by Sharma et al., 2006 and Khan et al., 2010.

**Number of effective tillers per plant**

Number of effective tillers per plant exhibited positive and significant association with biological yield per plant, length of main spike and number of spikelet per main spike at genotypic and phenotypic levels. This character showed highly significant and negative correlation with harvest index and significant and negative with grain weight per main spike at genotypic level by Sharma et al., 2006 and Khan et al., 2010.

**Length of main spike (cm)**

Length of main spike exhibited highly significant and positive correlation with number of spikelet per main spike and biological yield per plant. Length of main spike exhibited significant and positive correlation with number of grain per main spike at both genotypic and phenotypic levels. Whereas significant
and negative correlation with harvest index and 1000 grain weight was found for this character. (Singh et al., 2012 and Gelalcha and Hanchinal, 2013)

**Peduncle length of main spike (cm)**

Peduncle length of main spike was significantly and positively correlated with the grain weight per main spike only at genotypic level. Whereas remaining characters were non-significant at both the levels.

**Number of spikelet per main spike**

Number of spikelet per main spike showed highly significant and positive correlation with biological yield per plant and number of grain per main spike at both the genotypic and phenotypic levels. Significant and negative correlation between number of spikelet per main spike and harvest index and 1000 grain weight at genotypic and phenotypic levels were observed.

**Number of grains per main spike**

The number of grains per main spike was significant and positively correlated with grain weight per main spike and biological yield per plant.

**Grain weight per main spike (g)**

This trait showed highly significant and positive correlation with 1000 grain weight and biological yield per plant at both genotypic and phenotypic levels while harvest index was highly significantly and positively correlated at genotypic level and it was significant and positive at phenotypic level.

**1000 grain weight (g)**

The trait 1000 grain weight showed positive and significant correlation with biological yield per plant at genotypic level only.

**Biological yield per plant (g)**

The biological yield per plant showed highly significant and negative genotypic associations with harvest index at genotypic level only. Present finding are conformity with those reported earlier in wheat by Sharma et al., 2006; Khan et al., 2010; Bhushan et al., 2013; Gelalcha and Hanchinal, 2013; Kumar et al., 2013b and Kumar et al., 2014b. The present results on correlation coefficients thus, revealed that the biological yield per plant, grain weight per main spike, number of grains per spike, number of effective tillers per plant, 1000 grain weight, length of main spike and harvest index were the most important traits and may contribute considerably towards higher grain yield. The interrelationship among yield components would help in increasing the yield levels and therefore, more emphasis should be given to these components while selecting better types in wheat.

**Path coefficient analysis**

While correlation values clarifies the inter-relationship between different characters, path coefficient splits the amount of inter relationship into components, direct and indirect effects as exerted on dependent character. Therefore, in the present investigation the direct and indirect effect of different component characters as exerted on grain yield plant 

Path coefficient analysis indicated that the number of effective tillers per plant, number of grains per main spike, 1000 grain weight, biological yield per plant and harvest index exhibited high and positive direct effects on grain yield per plant. Thus, these characters turned-out to be the major components of grain yield. The characters like days to 50 % flowering, grain filling period, days to maturity and number of spikelet per spike exerted low and negative direct effects on grain yield per plant. The characters like plant height, length of main spike and peduncle length of main spike exerted low and positive direct effects on grain yield per plant. The characters grain weight per main spike exerted high but negative direct effects on grain yield per plant. Bhushan et al. (2013) and Gelalcha and Hanchinal, (2013) reported high and positive direct effect of biological yield per plant and harvest index on grain yield per plant in wheat. High and positive direct effects on yield via number of effective tillers per plant have been reported by Bhushan et al. (2013); number of grains per main spike by Sen and Toms (2007) and 1000 grain weight by Bhushan et al. (2013). The positive direct effects of plant height on grain yield have been reported earlier by Rangare et al. (2010); length of main spike by Ihsan et al. (2004) and peduncle length of main spike by Ihsan et al. (2004).

The negative direct effects of days to maturity on grain yield have been reported earlier by Singh et al. (2012). The grain filling period, days to 50 % flowering and number of spikelet per main spike exhibited negative direct effect on grain yield per plant have been reported earlier by Singh et al. (2007). The grain weight per main spike exhibited high and negative direct effect on grain yield per plant have been reported earlier by Rangare et al. (2010) and Bhushan et al. (2013).

The direct effect of number of grains per spike was high and positive on grain yield per plant, with positive effects via grain weight per main spike, number of spikelet per main spike, biological yield per plant and length of main spike. The direct effect of 1000 grain weight on grain yield was high and positive. This character also contributed indirectly by exhibiting positive effect via grain filling period, peduncle length of main spike, grain weight per main spike, biological yield per plant and harvest index. The character biological yield per plant exhibited high and positive direct effect and contributed indirectly by exerting positive indirect effect via all characters expect harvest index.
Table 1. Genotypic ($r_g$) and phenotypic ($r_p$) correlation coefficients among 14 characters in 50 genotypes of bread wheat

| Characters                              | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ | $r_g$ | $r_p$ |
|-----------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Days to 50% flowering                   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Days to maturity                        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Plant height (cm)                       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Number of effective tillers per plant  |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Length of main spike (cm)               |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Peduncle length of main spike (cm)      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Number of spikelet per main spike       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Grain weight per main spike (g)         |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 1000 grain weight (g)                   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Biological yield per plant (g)          |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

*, ** Significant at 5% and 1% levels, respectively
Table 2 Genotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on grain yield in 50 genotypes of bread wheat

<table>
<thead>
<tr>
<th>Characters</th>
<th>Days to 50% flowering</th>
<th>Grain Filling Period</th>
<th>Days to maturity</th>
<th>Plant height (cm)</th>
<th>Number of effective tillers per plant</th>
<th>Length of main spike (cm)</th>
<th>Peduncle length of main spike (cm)</th>
<th>Number of spikelet per main spike</th>
<th>Number of grains per main spike</th>
<th>Grain weight per main spike (g)</th>
<th>1000 grain weight (g)</th>
<th>Biological yield per plant (g)</th>
<th>Harvest index (%)</th>
<th>Genotypic correlation with grain yield/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days to 50% flowering</td>
<td>-0.1991</td>
<td>0.0978</td>
<td>-0.1816</td>
<td>-0.0899</td>
<td>-0.0491</td>
<td>-0.0291</td>
<td>0.0134</td>
<td>-0.0887</td>
<td>0.0153</td>
<td>0.0718</td>
<td>0.0625</td>
<td>-0.0353</td>
<td>0.1379</td>
<td>-0.2468</td>
</tr>
<tr>
<td>Grain Filling Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days to maturity</td>
<td>0.1154</td>
<td>-0.2349</td>
<td>0.0214</td>
<td>-0.0594</td>
<td>0.0150</td>
<td>-0.0468</td>
<td>-0.1068</td>
<td>-0.0269</td>
<td>-0.0477</td>
<td>-0.0466</td>
<td>-0.0410</td>
<td>-0.0341</td>
<td>0.1581</td>
<td></td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>-0.0164</td>
<td>0.0016</td>
<td></td>
<td>-0.0114</td>
<td>-0.0045</td>
<td>-0.0047</td>
<td>-0.0025</td>
<td>-0.0102</td>
<td>-0.0001</td>
<td>0.0058</td>
<td>0.0050</td>
<td>0.0004</td>
<td>0.1014</td>
<td>-0.2077</td>
</tr>
<tr>
<td>Number of effective tillers/plant</td>
<td>0.0317</td>
<td>0.0178</td>
<td>0.0447</td>
<td>0.0703</td>
<td>0.0160</td>
<td>0.0421</td>
<td>0.0408</td>
<td>0.0374</td>
<td>0.0197</td>
<td>0.0065</td>
<td>-0.0065</td>
<td>0.0348</td>
<td>-0.0361</td>
<td>0.2284</td>
</tr>
<tr>
<td>Length of main spike (cm)</td>
<td>0.0097</td>
<td>0.0132</td>
<td>0.0173</td>
<td>0.0396</td>
<td>0.0316</td>
<td>0.0126</td>
<td>0.0406</td>
<td>0.0214</td>
<td>-0.0016</td>
<td>0.0060</td>
<td>0.0004</td>
<td>0.0330</td>
<td>-0.0278</td>
<td>0.2713</td>
</tr>
<tr>
<td>Peduncle length of main spike (cm)</td>
<td>-0.0029</td>
<td>0.0195</td>
<td>0.0059</td>
<td>0.0249</td>
<td>-0.0043</td>
<td>0.0082</td>
<td>0.0429</td>
<td>0.0036</td>
<td>0.0115</td>
<td>0.0124</td>
<td>0.0041</td>
<td>0.0092</td>
<td>0.0009</td>
<td>0.2543</td>
</tr>
<tr>
<td>Number of spikelet per main spike</td>
<td>-0.0455</td>
<td>-0.0117</td>
<td>-0.0575</td>
<td>-0.0542</td>
<td>-0.0473</td>
<td>-0.0627</td>
<td>-0.0087</td>
<td>-0.1020</td>
<td>-0.0506</td>
<td>0.0033</td>
<td>0.0456</td>
<td>-0.0567</td>
<td>0.0702</td>
<td>0.1607</td>
</tr>
<tr>
<td>Number of grains per main spike</td>
<td>-0.0516</td>
<td>0.1368</td>
<td>0.0053</td>
<td>0.1887</td>
<td>-0.0410</td>
<td>0.2178</td>
<td>0.1807</td>
<td>0.3340</td>
<td>0.6734</td>
<td>0.4683</td>
<td>-0.1794</td>
<td>0.2600</td>
<td>0.1018</td>
<td>0.5027**</td>
</tr>
<tr>
<td>Grain weight per main spike (g)</td>
<td>0.1234</td>
<td>-0.0649</td>
<td>0.1105</td>
<td>-0.0317</td>
<td>0.0991</td>
<td>0.0081</td>
<td>-0.0987</td>
<td>0.0110</td>
<td>-0.2379</td>
<td>-0.3421</td>
<td>-0.1548</td>
<td>-0.1467</td>
<td>-0.1636</td>
<td>0.7855**</td>
</tr>
<tr>
<td>1000 grain weight (g)</td>
<td>-0.1898</td>
<td>0.1057</td>
<td>-0.1673</td>
<td>-0.0558</td>
<td>-0.1175</td>
<td>-0.1889</td>
<td>0.0582</td>
<td>-0.2702</td>
<td>-0.1612</td>
<td>0.2738</td>
<td>0.6051</td>
<td>0.1806</td>
<td>0.1755</td>
<td>0.5421**</td>
</tr>
<tr>
<td>Biological yield per plant (g)</td>
<td>0.1065</td>
<td>0.0816</td>
<td>0.1602</td>
<td>0.2969</td>
<td>0.3112</td>
<td>0.3001</td>
<td>0.1293</td>
<td>0.3335</td>
<td>0.2320</td>
<td>0.2576</td>
<td>0.1793</td>
<td>0.6007</td>
<td>-0.2733</td>
<td>0.8010**</td>
</tr>
<tr>
<td>Harvest index (%)</td>
<td>-0.1574</td>
<td>0.0032</td>
<td>-0.1784</td>
<td>-0.1166</td>
<td>-0.1266</td>
<td>-0.0955</td>
<td>0.0048</td>
<td>-0.1564</td>
<td>0.0343</td>
<td>0.1087</td>
<td>0.0659</td>
<td>-0.1034</td>
<td>0.2272</td>
<td>0.1576</td>
</tr>
</tbody>
</table>

*, ** Significant at 5% and 1% levels, respectively
Residual effect, R = 0.1307

N.B.: Values at diagonal indicate direct effects of respective character
In the present study, the characters like number of grains per main spike, grain weight per main spike, 1000 grain weight and biological yield per plant showed positive and significant association with grain yield per plant, as well as high and positive direct effect on grain yield per plant except grain weight per main spike. Hence, these characters may be considered as the most important yield contributing characters and due emphasis given on these components while breeding for high yielding types in wheat. This type of relationship is due to manifold effect of gene(s). It therefore becomes very difficult to partition such effects by selecting particular characters that are so related. Information obtained from correlation study cannot reflect or give complete idea about the contributors of each character. Therefore, it is important to establish the genetic basis of correlation before initiating breeding programme aimed at yield improvement through component traits. Path coefficient analysis is however, more useful for partitioning of direct and indirect causes of correlation and also enables breeders to compare the component factors on the basis of their relative contributors.

REFERENCES


DWR Vision (2030). Published by Project Director, DWR, Karnal.


