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Research Article

Association of Yield and Yield Related Traits in Bread Wheat (*Triticum aestivum L.*) Genotypes under Irrigation Condition in South Omo Zone, South Ethiopia

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Abstract

Wheat (Triticum aestivum L.) is a high yielder and wider adaptability of the staple food for alarge part of the world population including Ethiopia. 36 bread wheat varieties were conducted for correlation and path coefficient analysis of some quantitative traits in bread wheat at Jinka Agricultural Research Center in Ethiopia in the 2019/20 cropping season. The varieties were evaluated in the Triple lattice design. Data on yield and yield components were Collected and analyzed using SAS version 9.3 Software. Grain filling and plant height were significant and positively correlated at phenotypic and genotypic levels with days to maturity and number of kernels per spike, days to heading, and harvest index. The Phenotypic path coefficient analysis showed that biomass followed by seeds per spike and days to maturity exerted the highest positive direct effect on grain yield. The maximum positive genotypic direct effect on grain yield was exerted by days to maturity (1.358) followed by biomass yield (0.855), fertile tiller per plant (0.763), harvest index (0.383), number of kernel (0.305) and plant height (0.047). Generally, these relationships can be used as a selection in breeding studies to improve the high yielding cultivars for that target area.

Keywords: *Grain yield, Genetic distance, Genotypic correlation, Phenotypic correlation, Path coefficient.*

1. INTRODUCTION

World wheat production is based almost completely on two modern species: hexaploid bread wheat (Triticum aestivum L, 2n = 6X = 42, AABBDD) and tetraploid wheat (T. turgidum subsp. durum, 2n = 4X =28, AABB (Sears, 1966). Wheat can grow in the Ethiopian highlands, which are located between 6o and 16o N, latitude and 35o and 42oE, longitude at altitude ranging from 1500 - 3000 m.a.s.l. However, the most appropriate altitude zones of wheat fall between 1900 - 2700 m.a.s.l [1]. Dissimilar rice and maize, which prefer to tropical environment, wheat is extensively grown in temperate regions occupying 17% of all crop acreage worldwide. Currently, it is also attractive most important cereals grown on a large scale[2], because of its significance as cash crop, high level of production per unit area, its major role in providing the nutritional requirements of the society. Wheat is one of the major staple and strategic food security crops in Ethiopia [3] cultivated by half a million householders on about 1.7 million ha. Despite its incredible contributions to food and nutritional security of the country, the national average wheat productivity is 2.37 t/ ha far below the global average of 3.27 t/ha (4). Grain yield is a complex character that can be determined by several components which reflect positive or negative effects upon these traits[5]. It is important to examine the contribution of each of the various components in order to attract the attention to which one has the greatest influence on grain yield. Therefore, information on the relation of yield components with grain yield is of great importance to a breeder in selecting a desirable genotype[6]. A correlation coefficient is useful in quantifying the magnitude and direction of components influence in the determination of main characters. However, it did not provide the relative importance of direct and indirect effects of such components [7]. Through correlation coefficient analysis, revealed the positive correlation between grain yield and yield component traits in wheat such as harvest index [8], biological yield[9], grains per spike[9]and thousand kernels weight[10. Path coefficient analysis permits the partitioning of correlation coefficient into direct and indirect effects and facilitates the estimation of contribution of each component on grain yield[12]. A study on path analysis,[13], indicated that thousand grain weights had the highest positive direct effect on yield followed by spike length and days to heading while, plant height and grains per spike had negative direct effect on yield. The objectives of this study were: -

- To assess correlations among yield and yield-related traits under irrigation in bread wheat
- To determine the direct and indirect effects of yield-related traits on grain yield of bread wheat under irrigation

2. MATERIALS AND METHODS

2.1 Overview of the Experimental Site

Description	Location
	Bena-tsemy Weyito
Altitude (m.a.s.l.)	550 m a.s.l
Mean annual rainfall(mm)	750 mm
Mean annual temperature(oc)	22 °C and 32°C
Soil type	Sandy loam soil and with pH of 7.9-8.1

Source: - (Haileslassie *et a*l., 2015).

2.2 Planting Materials

The experimental materials contained of 36 bread wheat varieties. That includes 36 selected bread wheat varieties in Ethiopia from werer Agricultural Research Centers until the year, 2016 were collected. Most of the varieties were collected from the wheat center of Excellency at werer Agricultural Research Center the detail information's are presented (Table 2).

Table 2: List of bread wheat Genotypes with the origin information.

Trt.no	GENOTYPE	Origin
1	HUBARA-3*2/SHUHA-4	CIMMYT/ICADA
2	FLORKWA2/6SKER'S'/5/ANZA/3/KVZ/HYS/YMH/TOB/4/BOW	CIMMYT/ICADA
3	PRINI-1//NESMA*2/14-2/3/DUCULA	CIMMYT/ICADA
4	Atila-7	CIMMYT/ICADA
5	ETBW5535	CIMMYT/ICADA
6	KAUZ'S'/FLORKWA-1//GOUMRIA-3	CIMMYT/ICADA
7	ETBW5957	CIMMYT/ICADA
8	ATTILA/AWSEQ-4	CIMMYT/ICADA
9	Fentale	CIMMYT/ICADA
10	ADEL-2	CIMMYT/ICADA
11	DAJAJ-1/VEE'S'/SAKER'S'	CIMMYT/ICADA
12	PASTOR-2/HUBARA-5	CIMMYT/ICADA
13	KAUZ'S'/FLORKWA1//GOUMRIA-3	CIMMYT/ICADA
14	HIDDAB/ATTILA-7	CIMMYT/ICADA
15	PASTOR-2/HUBARA-5	CIMMYT/ICADA
16	HUBARA-5/ANGI-1	CIMMYT/ICADA
17	GAMBO	CIMMYT/ICADA
18	BJY/COC/PRL/BOW/3/BLOYKA-1	CIMMYT/ICADA
19	KAU'S'/FLORKWA-1//GOUMRIA-3	CIMMYT/ICADA
20	ANGI-2/HUBARA-3	CIMMYT/ICADA
21	TAGANA	CIMMYT/ICADA
22	JNRB.5/PIFED	CIMMYT/ICADA
23	PBW343*2/KUKUNA//KIRITATI	CIMMYT/ICADA
24	HUBARA-3*2/SHUHA-4	CIMMYT/ICADA
25	IMAM	CIMMYT/ICADA
26	KATILA17/DEEK2/8VEE'S'/7/CEBECO148/3/RON/CHA//NOR67/5/HK/38M	CIMMYT/ICADA
27	HUBARA-2/QAFZAH-21//DOVIN-2	CIMMYT/ICADA
28	INQALAB91*2/TUKURU//WHEAR	CIMMYT/ICADA
29	ATILA*2//ATTILA/BCN/3/STAR*3/MUSK-3	CIMMYT/ICADA
30	Werer-2	CIMMYT/ICADA
31	ATTILA50Y//ATTILA/BCN/3/STAR*3/MUSK-3	CIMMYT/ICADA
32	LUCY	CIMMYT/ICADA
33	Amibara	CIMMYT/ICADA
34	Fentale-2	CIMMYT/ICADA
35	Kakaba	CIMMYT/ICADA
36	Amibara -2	CIMMYT/ICADA

2.3. Experimental Design and Trial Management

The experiment was carried out in a 6 x 6 triple Lattice design comprising of six incomplete blocks. The genotypes were grown under irrigation conditions. Each genotype was sown in six rows of 3 meter long. Apart, with seed rate of 150 kg/h. Planting was done by hand drilling on July 05, 2012.Recommended fertilizer rate of 100 kg/ha N/P2O5 in the forms of Urea and DAP was applied to each plot in the shallow furrow depths and mixed with soil at the same time during sowing. All other crop management practices were applied uniformly to all plots as required.

2.4. Data Collected

Data on agro morphological traits of wheat varieties were collected on plot and plant basis on the following characters viz., Days to heading, Days to maturity, Grain Filling Period, Thousand Kernel Weight, Grain Yield, Biomass Yield, Harvest Index, Plant Height, Spike Length, Number of Kernels per Spike, and Number of spikelets per spike. The data were subjected to analysis of correlation and path coefficient according to a general linear model using SAS 9.3 (SAS Institute, 2012) and Microsoft Excel (2010). Estimation of correlation coefficients (r) is study positively and negatively correlated characters with yield and among themselves.

3. Results and Discussion

3.1. Phenotypic and Genotypic Correlation Coefficient

3.1.1. Correlation of grain yield with other characters

Days to heading and biomass yield both at phenotypic and genotypic levels had positive and highly significant correlations with grain yield. In addition, at phenotypic level, plant height, days to maturity, seeds per spike and harvest index had positive correlation with grain yield (Table 3). At phenotypic level biomass yield and thousand seed weight shows highly significant and significant correlation with grain yield. In contrast to these results,[13] and [14]found that at genotypic level, grain yield per hectare showed a positive and highly significant association with harvest index and biological yield. At phenotypic level, days to maturity and number of spikelets per spike with days to heading and grain filling period have highly significantly and positively correlated to each other. These findings are also in line with, [13][18] those reported at phenotypic level, plot yield was highly significantly and positively correlated with number of tillers per plant, grains per spike, thousand-grain weight, biological yield and harvest index. Similarly grain yield had positive and significant association with number of fertile tillers, biomass yield, spike length and number of grains per spike[15];[21];[20]. Khan *et al*. (2003) and Aycecik and Yildirim (2006) also showed significant and positive correlation between grain yield and number of tillers per plant. Grain yield showed negative association with spike length, number of kernels per spike, number of spikelets per spike and grain filling period both at phenotypic and genotypic levels (Table 2). The negative correlation of these traits with grain yield suggested that as genotypes were selected for spike length, number of kernel, number of spikelets per spike and grain filling results selection of genotypes for low yield. This result is consistent with the results reported by 15Basazen and Getachew (2014) where the correlation of grain yield with days to heading and days to maturity were significant and negative in lines of triticale (x.triticosecalewittmak) at both phenotypic and genotypic levels.[16] also reported negative and significant correlation of grain yield with days to heading.[17] also revealed negative phenotypic correlation of grain yield with days to heading in bread wheat genotypes tested in moisture deficit conditions.[18] and [19] reported that highly significant and positive correlation of yield per plot with days to heading.

3.1.2. Estimates of correlation among other characters

At phenotypic and genotypic levels, days to heading had positive and highly significant correlation with days to maturity and biomass yield but it showed a negatively significant correlation-with thousand seed weight (Table 2). Characters like grain filling and plant height were significant and positively correlated at phenotypic and genotypic levels with days to maturity and number of kernel per spike, days to heading and harvest index. Plant height exhibited positive and significant correlation with days to maturity at genotypic and phenotypic levels and significant with 50% days to heading phenotypically, in contrary with a finding reported by[20] where by plant height showed a significant positive correlation with above ground biomass at both genotypic and phenotypic levels. Similarly, significant positive phenotypic association of plant height with spike length, biological yield, tillers per m2 and grains also were founded by [21]. At both levels, grain filling period showed positive and significant with days to maturity and number of kernel per spike.

Fertile tillers per plant and thousand seed weight showed positive and highly significant association with harvest index and number of seeds per spike at both levels respectively. These findings are also in line with the findings of [22] concerning showing that the number of spikelets per spike showed a significant positive relation with spike length. [23] and [14] were reported highly significant association of days to heading with seeds per spike and spikelets per spike. [20] also reported that days to heading showed significant positive correlation with days to maturity (r= 0.92), above-ground biomass (r=0.61), plant height (r = 0.47), spikelet's per spike(r=0.74) and spike length. In contrary with this finding, non-significant genotypic correlation of biomass yield with days to heading and days to maturity as reported by 16Adhiena et al. (2016). [22] reported that negative associations of days to maturity with plant height and spike length.

At genotypic level, days to heading shows highly significant to days to maturity, biomass yield, 1000 kernel weight and grain yield and grain filling period also significant to days to maturity and number of kernels. At genotypic level, number of spikelets per spike had positive relationship with spike length, in contrast with results reported by [24]. At genotypic level, negative relationship of number of spikelets per spike with spike length was obtained. Number of fertile tillers per plant had positive and highly significant phenotypic correlation with thousand-kernel weight (Table 2).

Spike length showed positive highly significant phenotypic correlation with number of spikelets per spike. At genotypic level, the coefficient of correlation for days to maturity with days to heading and grain filling period, spikelets per spike with days to heading, spike length with number of spikelets per spike, Biomass yield and grain filling period were showed positive and highly significant with, days to heading, number of kernels per spike respectively. Days to heading exhibited positive and highly significant phenotypic correlation with days to maturity at phenotypic and genotypic level whereas at phenotypic level significant with biomass yield, thousand kernel weight and grain yield and at genotypic level significant correlation with plant height and number of spikelets per spike. Spike length had negative and highly significant phenotypic correlation only with number of spikes per spike at genotypic level and phenotypic association with seeds per spike. In line with this result, [23] stated that positive significant associations were observed for spike length with number of kernels spike-1 at genotypic level.

Number of tillers per plant positively associated with 1000 seed weight (Kumar *et al.,* 2013). In contrast, spike length had significantly negative genotypic correlation only with days to 50% maturity [24]. The Spike length also showed non-significant negative associations with days to maturity at phenotypic [25]. Effective tillers per plant showed negative and highly significant correlation with thousand kernel weight at genotypic and phenotypic level in contrary with the results of [26]. Effective tillers per plant showed negative and significant correlation with spike length and number of grains per spike respectively at genotypic and phenotypic level. Days to heading showed positive and highly significant correlation with days to maturity at both phenotypic and genotypic level, and with number of spikelets per spikes at phenotypic level and also significant with plant height at phenotypic level. At genotypic level, days to heading showed positive and highly significant correlation with biological yield, grain yield and significant correlated with thousand kernel weight. Days to heading showed negative correlation with grain filling period, number of kernels per spike and number of grains per spike both at phenotypic and genotypic levels (Table 3). Days to maturity showed negative and highly significant genotypic correlation with grain filling period and positively significant phenotypic correlation with biological yield. Phenotypic correlation of days to heading showed negatively significant with thousand-kernel weight and genotypic correlation was none significant.

The grain filling period exhibited highly significant and positive phenotypic association with days to maturity. However, it had a negative association with spike length, grains per spike and thousand kernel weight as well as genotypic correlation significant with days to maturity and number of kernels per spike and it shows negative association of days to heading, plant height, fertile tiller per plant, spike length and grain yield at the genotypic level. At phenotypic and genotypic, number of fertile tillers per plant, spike length and number of spikelets per spike showed negative none significant correlation with biological yield, plant height, thousand seed weight and harvest index respectively. Spike length showed negative and highly significant genotypic association with number of spikelets per spike and positive significant association with seeds per spike. Number of fertile tillers per plant showed negative highly significant phenotypic association with thousand seed weight. Biomass yield also show positive and highly significant with days to heading and days to maturity at genotypic and phenotypic level with thousand kernel weight and grain yield. As well as positive association with grain filling period and plant height. Thousand kernel weight depicted negative highly significant correlation with fertile tiller per plant at both phenotypic and genotypic level and significant association with days to heading and number of kernels per spike, as well as, negative correlation with harvest index at phenotypic and highly significant correlation with biomass yield and significant association with yield genotypic level (Table or Appendix). Contrary results were reported by [27] reported that days to maturity showed negative and significant association with number of tillers plant-1 at the genotypic level.[20] reported that 1000- kernel weight showed significant negative correlation with spike length and spikelets per spike.[25] reported that days to maturity had negative and significant phenotypic correlation with thousand kernel weight and harvest index and harvest index exhibited significant negative correlation with biomass yield in bread wheat at genotypic level.

In contrast, to this study Significant negative correlation was detected between harvest index and biomass yield in spring bread wheat [28]and Rameeh, 2016). At genotypic level, 1000-grain weight shows positive and negative significant correlation with number of kernel and 50% days to heading and also negative highly significant with fertile tiller per plant. The Disagreement result were reported by [21], who showing that 1000-grain weight had positive association with days to heading and days to maturity, plant height, spike length and significant positive association with number of spikelets per spike.

The character number of productive tillers per plant showed negative and highly significant correlation with 1000 kernel weight at both genotypic and phenotypic level. Contrast to 25expressed that, number of productive tillers per plant showed significant and positive correlation with days to 50% heading at phenotypic and genotypic level. Days to maturity showed positive and significant association with grain filling period at both phenotypic and genotypic level. Opposite to [31], days to maturity showed positive and significant association with number of productive plant -1 and thousand kernel weight. Highly signify positive correlation of spike length with number of spikes per plant was observed at phenotypic level, and significant with seeds per spike was observed at genotypic level. [16] reported highly significant positive correlation of spike length with number of spikelates per spike.

Table 3: Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient of the 12 quantitative traits of bread wheat genotypes.

Traits	HD	GFP	DM	PH	FTPP	SPN	SPL	KPN	SPS	BY	TKW	GY
HD	**1.000**	-0.086	0.594**	0.249	0.100	0.269	-0.123	-0.302	-0.087	0.482**	-0.351*	0.516**
GFP	-0.088	**1.000**	0.357*	-0.002	-0.218	0.119	-0.143	0.400*	0.048	0.004	0.154	-0.119
DM	0.590**	-0.355**	**1.000**	-0.068	-0.034	-0.152	-0.069	-0.125	-0.104	0.391*	-0.032	0.214
PH	0.242*	0.003	0.065	**1.000**	0.166	-0.116	-0.081	0.243	-0.161	0.166	-0.124	0.278
FTPP	0.078	0.144	-0.018	0.139	**1.000**	0.256	0.315	-0.251	-0.088	-0.001	-0.527**	-0.006
SPN	0.226**	0.114	-0.134	-0.124	0.150	**1.000**	0.143	0.016	0.459*	-0.033	0.056	-0.144
SPL	0.153	-0.015	0.194	0.175	-0.035	-0.245**	**1.000**	0.316	0.367*	-0.033	-0.134	-0.156
KPN	-0.052	0.078	0.045	-0.080	0.117	-0.182	0.093	**1.000**	0.335	-0.057	0.354*	-0.146
SPS	-0.081	-0.058	0.053	0.004	0.152	-0.035	-0.109	-0.154	**1.000**	-0.052	-0.037	0.02
BY	0.027	0.150	- 0.084	0.009	-0.05	-0.097	-0.117	0.232**	-0.158	**1.000**	-0.043	0.406*
TKW	-0.057	-0.029	-0.091	0.130	-0.029**	-0.074	-0.005	-0.070	-0.075	0.375**	**1.000**	-0.221
GY	-0.046	0.150	0.010	0.130	-0.120	-0.142	-0.061	-0.01	-0.172	0.354**	0.186*	**1.000**

and, significant at P<0.05 and P<0.01, respectively. PH=plant height, HD=days to heading (days), GFP=grain filling period (days), DM=days to maturity (days), FTPP =fertile tiller per plant, SPL=Spike length (cm), SPS= Spikelets per spike, KPS= number of kernels per spike, TKW= Thousand-kernel weight, BY=biomass yield (kgplot-1), GY=grain yield t ha-1.*

3.2. Path Coefficient Analysis

Path coefficient analysis measures the direct and indirect contribution of independent variables on dependent variables and thus helps the breeder to determining the yield components and understanding cause of association between two variables [18]. When characters having direct bearing on yield are selected, their associations with other characters are to be considered simultaneously as this will indirectly affect the yield. In this study, grain yield was selected as dependent variable and 12 traits that had significant correlation with grain yield were selected as casual variables. The results of path analysis for direct and indirect effects of the characters studied both at genotypic and phenotypic level are indicated in (Table 4 and 5).

3.2.1. Phenotypic direct and indirect effects of traits on grain yield

Biomass followed by seeds per spike and days to maturity exerted highest positive direct effect on grain yield and harvest index and seeds per spike had positive significant phenotypic correlation (Table 3). Likewise, thousand seed weight, plant height and harvest index exerted positive and small magnitude of direct effect but with positive and highly significant phenotypic association with plant height, thousand kernel weights and negative association of harvest index with grain yield. From the correlation and path analysis of this experiment biomass yield, seeds per spike and days to maturity could be considered as main components for selection of grain yield in a wheat breeding program. The low direct effect of thousand seed weight, plant height and harvest index and their highly significant phenotypic correlation with grain yield was due to the cumulative indirect effect of these traits through other. Biological yield and seeds per spike and days to maturity, 1000 kernel weight and harvest index had high positive direct effect on the grain yield. Accordingly, this result agrees with the findings of [20]and[13 in terms of biomass and harvest index had high direct effect on grain yield and suggested that the relationship between these traits as good contributors to grain yield in durum and bread wheat genotypes. The result is also in line with 25Berhanu (2004) who reported that biological yield and harvest index were also the most important traits directly affecting yield phenotypically. Under drought condition, [15], above ground biomass and harvest index exerted positive direct effect on grain yield and concluded that these characters are good measurement for predicting grain yield. The same author reported that a number of spikes per plant and number of grains per spike exerted insignificant direct effects on grain yield.

The result is disagreeing with [26] who reported the direct effects of biological yield per plant was negative and suggested that the correlation coefficient was positive due to the indirect effects via effective tillers per plant and harvest index so that the direct selection for this trait to improve yield was undesirable. However, days to heading which had negative highly significant correlation exerted strongly negative direct effect and days to maturity positive direct effect on yield phenotypically. Whereas, the number of kernels per spike had negligible negative direct effect however, it had positive highly significant correlations on grain yield. Hence, the positive phenotypic correlation coefficient of plant height with grain yield was due to the indirect effect. These results are in disagreement with [32]. Moderate positive

indirect effect was exerted by days to maturity and days to heading through Plant height but they exhibited strong negative indirect effect via Spike number per spike, spike length and number of kernels per spike. Harvest index also exerted moderate negative indirect effect through days to maturity and days to heading. Days to heading exerted a strong negative indirect effect through Fertile tiller per plant and Biomass yield while it exerted moderately positive indirect effect through Harvest index.

The considerable negative indirect effect exerted on grain yield by plant height through days to heading and biomass yield at the phenotypic level negative direct effect on grain yield. The result is in accordance with [26], the direct effect of days to maturity was negative and moderate on grain yield. However, the result is in line with the results of (24) showing positive direct effects of days to maturity on grain yield and with the suggestion of more days to maturity would be an important selection criterion for improved grain yield plant-1 in the breeding material studied. Accordingly, with [26] reported that the highest positive direct effect plant height on grain yield. (29) also indicated plant height had a strong positive direct effect on grain yield. Low positive direct effect was exhibited by plant height and number of kernels per spike (19) Grain filling period, spikelets per spike and spike length exerted positive considerable indirect effect via days to heading, Days to maturity and seeds per spike while these traits exhibited strong negative indirect effect through fertile tiller per plant, thousand seed weight and biomass yield (Table 3). The result suggested that traits like spike length, number of fertile tillers per plant and biomass yield caused increasing of grain yield indirectly. This result agrees with the finding of [30] who reported that the indirect effect of plant height via number of productive tillers per plant was negative and high, with the suggestion that the selection for this trait will not be effective. This result also agrees with [19] who reported days to maturity showed positive indirect effect via above-ground biomass. The indirect effect of biomass through days to heading (-0.029), days to maturity (-0.009) and harvest index (-0.005) counter balanced the direct effect of biomass on grain yield and reduced the correlation coefficient to (0.316). This showed that the correlation it has with grain yield is not only due to the direct effect but also indirect effect which can be used for yield improvement during selection.

The indirect effect of harvest index through days to heading (-0.001) days to maturity -0.001) and biomass -0.046) counter balanced the direct effect of harvest index (0.077) on grain yield. The indirect effect of spike length through days to heading (0.025) and biomass yield (-0.037), counter balanced the direct effect of spike length (-0.074) on grain yield and reduced the correlation coefficient to -0.278. Therefore, whenever selection is made for improved grain yield, all these characters should be considered. In similar way, the findings of 25also indicated that in directed effect of harvest index through biomass yield (-0.202) counter balanced the direct effect of harvest index (0.919) on grain yield. The residual effect in path analysis determines how best the component (independent) variables account for the variability of the dependent variable, which is grain yield 35(). The residual effect in the present study was 0.3210 (Table 5), showing that 67.9% of the variability in grain yield was explained by the factors. The remaining 32.1% is explained by other traits not considered in the study. This further clarified that yield attributing traits chosen for the study of the bread wheat genotypes were good.

Table- 4. Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of different traits on grain yield at phenotypic level in 36 bread wheat genotypes.

Traits	DH	GFP	DM	PH	FTPP	SPN	SPL	KPS	SPS	BM	TKW	HI	RP
DH	**-0.120**	0.042	0.067	0.006	-0.006	-0.029	-0.011	-0.001	-0.011	0.008	-0.005	0.008	-0.046
GFP	0.037	**-0.062**	0.040	-0.001	-0.011	-0.014	-0.001	-0.001	0.008	0.007	-0.002	0.004	0.097
DM	0.047	-0.022	**0.115**	0.001	0.001	-0.017	-0.014	-0.001	0.007	-0.026	-0.009	-0.001	0.015
PH	0.032	0.001	0.007	**0.026**	-0.011	0.016	-0.013	0.001	0.001	0.002	0.012	0.010	0.010
FTPP	-0.014	-0.008	-0.002	0.003	**-0.080**	-0.019	0.002	-0.001	0.021	-0.017	-0.002	0.007	0.057
SPN	0.040	-0.007	0.015	-0.003	-0.012	**-0.130**	0.018	0.003	-0.004	-0.030	-0.001	0.002	-0.120
SPL	0.025	-0.001	0.022	0.004	0.002	0.032	**-0.074**	-0.002	-0.015	-0.037	-0.001	0.001	-0.135
KPS	-0.053	-0.004	0.005	-0.002	-0.001	0.023	-0.006	**-0.021**	0.021	0.073	-0.007	-0.003	-0.061
SPS	-0.012	-0.003	0.006	0.0001	-0.012	0.004	0.008	-0.003	**0.140**	0.050	-0.007	-0.007	0.172
BM	-0.012	0.001	-0.009	0.001	0.004	0.012	0.013	-0.005	0.022	**0.316**	0.037	-0.005	0.354
TKw	-0.014	0.001	-0.010	-0.010	0.003	0.002	0.009	0.001	0.001	0.118	**0.099**	-0.011	0.186
HI	-0.001	-0.003	-0.001	0.003	-0.008	-0.004	-0.001	0.001	-0.014	-0.046	-0.014	**0.077**	-0.025

Residual = 0.3210, *and**, significant at P<0.05 and P<0.01, respectively and rp=phenotypic correlation

3.3.2. Genotypic direct and indirect effects of traits on grain yield

The maximum positive genotypic direct effect on grain yield was exerted by days to maturity (1.358) followed by biomass yield (0.855), fertile tiller per plant (0.763), harvest index (0.383), number of kernel (0.305) and plant height (0.047). The trait grain filling period, days to heading, seeds per spike, spike length and 1000 kernel weight had shown negative genotypic correlations. (Table 5). The result indicated that the positive high correlation of days to maturity, biomass yield and fertile tiller per plant with grain yield at genotypic level was due to the direct effect of these characters on grain yield. Hence, days to maturity, plant height, and number of tillers per plant, biomass yield, more number of tillers per plant, biomass yield should be considered in further selection procedures for higher grain yield. The results reported in this study is in agreement with (31 and25). The positive genotypic direct effect for days to maturity on grain yield in bread wheat were reported by many authors. The days to maturity and productive tiller per plant had direct effect and positive significant association with grain yield. Days to maturity (1.358) and biomass yield (0.855) exerted the highest positive direct effect on grain yield and indicated that the main contributors to grain yield (59). On the other hand, the present result is in contradiction to the results of (25); who reported negative and moderate direct effect of days to maturity on grain yield at genotypic level in bread and durum wheat genotypes respectively. Days to maturity (-0.014) showed negligible negative direct effect to the grain yield (20). Fertile tillers per plant had negative direct effect on grain yield per plant with a value of (-9.938).

The genotypic correlation coefficients of days to heading (-2.021) and grain filling period (-1.022) were significant and negative with grain yield. However, these characters had low negative direct effect on grain yield. This indicates that even if the indirect effects of these characters (days to heading and grain filling period) on grain yield through other characters were too small its cumulative effect could be the cause for significant and negative correlation. However, the negative effects are in consistent with the results of 31who reported negative direct effects of days to heading, grain filling period and thousand-kernel weight on grain yield. 32) also reported that days to heading (-0.79), days to maturity (-0.76), plant height (-0.63), and grain filling period (-0.21) had direct negative effect on grain yield per plant. Number of fertile tillers per plant and harvest index showed a strongly negative indirect effect through days to maturity.

Furthermore, fertile tiller per plant exerted strong positive indirect effect through harvest index. Whereas, days to maturity and kernel number exhibited strong negative indirect effect with grain yield through harvest index at genotypic level. The considerable positive direct effect but negatively and highly significant correlation of days to maturity with grain yield was due to the indirect effect of days to maturity on grain yield mainly through harvest index and number of fertile tiller per plant. However, grain filling period exerted moderate positive indirect effect with grain yield via days to maturity. Plant height exerted moderate positive indirect effect with grain yield through days to maturity and harvest index respectively. Similar results were also observed by (14) that the highest positive indirect effect of days to heading was recorded via days to maturity. 25) also reported that negative indirect effects were exerted by harvest index via days to heading, and harvest index via days to maturity on grain yield. The character days to maturity had positive direct effect on grain yield, which suggests that the selection for early maturing lines with high yield is possible 33. Similar to this result (13) noticed that the highest positive indirect effects on yield were observed for a number of tillers per plant, followed by 1000 kernel weight, both via days to maturity. This result in part agreed with (34) and), who indicated that the existence of strong positive correlation and the significantly high magnitude effect of number of tiller per plant with grain yield through spike length and harvest index in bread wheat.

The strong indirect effect of harvest index through days to maturity (-0.032) and number of tillers per plant (0.763) counter-balanced the positive direct effect of harvest index (0.383) on grain yield and reduced the correlation coefficient to 0.099. Similarly, the considerable indirect effect of number of fertile tiller per plant through days to maturity -0.046) and harvest index (0.076) were- counter-balanced the direct effect of number of fertile tiller per plant (0.763) on grain yield and reduced the correlation coefficient to -0.006. The indirect effect of days to maturity mainly through harvest index (-0.009), number of fertile tiller per plant (-0.026) counter balanced the direct effect of days to maturity on grain yield and reduced the correlation coefficient to (0.214). But, their negative indirect effects through other characters need to be handled wisely. So this generally shows the Neutralize system of the traits each other for deleterious effect. This is partially in agreement with the findings of the indirect effect of harvest index through spike length (-0.01), number of spikelets per spike (-0.01), thousand kernel weight (-0.01) and biomass (-0.44) counter balanced the direct effect of harvest index on grain yield and reduced the correlation coefficient to (+0.69). The residual effect was 0.212 (Table 4), indicating that all the traits included in the study explained high percentage of variation in grain yield (kg ha-1) (78.8%) while other factors not included in the study can explain (21.2%). So that, yield components used were good. It is also suggested that further study should be made with more characters to find out other traits which contribute rest of the percentage of the yield. The residual effect (0.212) indicated that most of the variability in grain yield for the genotypes under the present has been explained by the independent variables included in the analysis.

Table- 5. Estimates of direct (bold and underlined diagonal) and indirect effect (off-diagonal) of different traits on grain yield at genotypic level in 36 bread wheat genotypes.

Trait	DH	GFP	DM	PH	FTPP	SPN	SPL	KPS	SPS	BM	TKW	HI	RG
DH	**-2.021**	0.088	0.806	0.011	0.076	-0.017	-0.031	0.018	0.052	0.018	0.033	0.080	-0.486
GFP	0.175	**-1.022**	0.485	-0.0001	0.166	-0.007	-0.041	0.018	-0.031	0.033	0.008	0.031	0.154
DM	-1.200	-0.365	**1.358**	0.003	-0.026	-0.009	-0.041	0.018	-0.034	-0.098	0.037	-0.009	0.009
PH	-0.504	0.002	0.092	**0.047**	0.127	0.007	-0.035	-0.040	0.019	-0.02	-0.053	0.090	0.060
FTPP	-0.203	-0.223	-0.046	0.007	**0.763**	-0.016	0.009	-0.019	-0.093	-0.134	0.009	0.076	0.184
SPN	-0.544	-0.121	0.206	0.007	0.195	**-0.064**	0.056	-0.066	-0.007	-0.047	0.015	0.0003	-0.146
SPL	-0.430	-0.019	0.382	0.011	-0.049	0.024	**0.146**	0.056	-0.001	-0.153	0.019	0.040	-0.098
KPS	-0.124	-0.090	0.084	-0.006	-0.049	0.014	-0.026	**0.305**	-0.086	0.183	0.018	-0.007	-0.019
SPS	0.239	-0.072	0.103	-0.002	0.159	-0.001	-0.001	0.059	**-0.447**	0.137	0.076	-0.019	0.257
BM	-0.042	-0.039	-0.156	-0.001	0.119	-0.003	-0.026	0.065	-0.072	**0.855**	-0.131	-0.019	0.489
TKW	0.235	-0.031	0.178	0.008	-0.256	0.003	0.009	-0.019	0.119	0.392	**-0.286**	-0.012	0.257
HI	-0.425	-0.084	-0.032	0.011	0.763	-0.390	-0.015	-0.005	-0.097	-0.042	0.009	**0.383**	0.567

Residual = 0.212 *and**, significant at P<0.05 and P<0.01, respectively and rg=genotypic correlation

4. CONCLUSION

The genotypic correlation analysis study revealed that the grain yield had strong and positive correlation with days to maturity, thousand kernels weight, hectoliter weight, harvest index and number of kernels per spike. The genotypic direct effect of harvest index, thousand kernel weight, days to maturity, number of grains per spike and hectoliter weight were positive while the plant height was negative. The highest positive indirect effect of the harvest index showed via thousand Kernel weights followed by plant height then number of grains per spike on grain yield. The character harvest index had highly significant direct effect at both phenotypic and genotypic and coupled with strong positive correlation to grain yield. This has been indicating that more attention should give to this character to improve the grain yield of bread wheat.

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CONFLICT OF INTEREST

The author declares no conflict of interest

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