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Correlation and Path Coefficient Analysis of Agro-Morphological Traits among Bread Wheat (*Triticum Aestivum* L.) Genotypes at Raya Valley of Southern Tigray, Ethiopia

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ABSTRACT

The correlations and path coefficient were studied in 36 diverse genotypes of bread wheat to understand the relationship and contribution of 12 characters towards the grain yield. Therefore, this field experiment was conducted to determine the association among traits and estimate the direct and indirect effects of traits on grain yield. The field evaluation of 32 genotypes and 4 released varieties was conducted in 6 x 6 Triple Lattice Design at Mehoni Agricultural Research Station in the 2017 cropping season. Results of analysis of variance revealed the presence of significant differences among genotypes for 12 quantitative traits. Grain yield was highly significantly and positively correlated with fertile tillers per plant and harvest index both at genotypic and phenotypic levels. The two traits had also high positive direct effects and indirect effects via days to heading and fertile tillers per plant both at genotypic and phenotypic levels. This suggested that the two traits could be used as the indirect selection of genotypes for yield. Whereas days to heading, grain filling period, and days to maturity had negative and significant correlation with grain yield both at genotypic and phenotypic levels and in-depth fertile tillers per plant and harvest index traits had also a negative direct effect on yield at the genotypic level.

Keywords: Correlation; Genotypes and Path coefficient.

1. INTRODUCTION

In Ethiopia, wheat is one of the major staples and strategic food security crops, and accounts for approximately 11% of the national calorie intake. Ethiopia is the second largest wheat producer in sub-Saharan Africa after South Africa. It is cultivated on 1.7 million hectares of land and has the production of 4.54 million tons with remain low productivity of 2.67 t ha^{-1} (CSA, 2017) in the country as compared to the world average yield (3.34 t ha^{-1}) (FAO, 2017).Wheat is producing in Tigray regions which relativelylager as compared to other crop of the area. The total wheat area and production in Tigray region was 0.12 million hectares and 0.21 million tons with the average yield of 1.98 t ha^{-1}.Wheat standssecond both in area and production among all crops followed by barely and *tef*. In the southern zone, the area coverage and productivity of wheat was 0.05 million hectares and 0.10 tons with the average yield of 2.072 t ha^{-1} respectively which is lower than from national (CSA, 2017).

The study of associations among various traits is useful to breeders in selecting genotypes possessing groups of desired traits. Correlation coefficient measures the relationship between two variables or it is the regression coefficient, which measures the rate of change in one variable or dependent variable per unit rate of change in another variable or independent variable. Correlation coefficients have been used for determining the relationship between the traits of crops (Dabholkar, 1992).Correlation among different traits is generally due to the presence of linkage and pleotropic effect of different genes. Environment plays an important role in the development of phenotypic correlation (Ali *et al.*, 2009). Phenotypic correlation is the net result of genetic and environmental correlation. The dual nature of phenotypic correlation makes it clear that the magnitude of genetic correlation cannot be determined from phenotypic correlation (Anwar *et al.*, 2009). Correlation coefficients may range in value from -1 to +1. Phenotypic correlations can normally be estimated with a high degree of accuracy. Estimates of genetic correlations, however, usually have high standard errors because of difficulties to avoid the directional effects of confounding factors (i.e. dominance and epistatic genetic effects) on additive genetic correlation estimates (Amsal, 2001).

Path coefficient analysis provides a clue on the contribution of the various components of the yield to the grain yields of the genotypes used in the study. Correlation and path coefficient analysis can be used as an important tool to generate information about appropriate cause and effects relationship between yield and some yield components (Khan and Dar, 2009). Path coefficient analysis provides an effective way of finding out direct and indirect sources of correlations. Selection for yield based on highly correlated characters becomes easy if the contribution of different characters to yield is quantified using path coefficient analysis (Dewey and Lu, 1959).

Raya Valley is the part of Southern Zone of Tigray Regional State; however, neithercorrelationstudies in wheat genotypes nor introduction of improved wheat varieties were attempted. This is due to the insufficient rain fall to support the growth and yield production of wheat in the area and the largest part of the valley is at low altitude (≤1600m.a.s.l.) experiencing warm to hot weather conditions. But, the dependence on rainfall alone in the area has in recent years been gradually replaced by supplemental irrigation and irrigated crop production. The number of farmers and investors using irrigation and supplemental irrigation is increasing. However, the absence of recommended varieties for the area remains as one of the major wheat production constraints in the area. Therefore, it is necessary to undertake research to develop wheat varieties for which association among traitsis very important. Thus, the present research was undertaken with the following objectives:-

- To determine association among traits and the direct and indirect effects on grain yield.

3. MATERIALS AND METHODS

3.1. Description of the Experimental Area

The study was carried at the research station of Mehoni Agricultural Research Center (MhARC) under supplemental irrigation in the 2017 main cropping season. Mehoni is located in Raya Valley in the northern parts of Ethiopia about 668 km from county's capital city of Addis Ababa, and about 120 km South of Mekelle, the capital city of Tigray regional state, Northern Ethiopia. Geographically, the experimental site is located at 12° 41'50" N latitude and 39° 42'08" E longitude with an altitude of 1578m.a.s.l. The site receives mean annual rainfall of 750 mm with an average minimum and maximum temperature of 22 °C and 32 °C, respectively. The soil type and textural class of the experimental area is vertysoil and clay loam respectivelywith pH of 7.9-8.1 (Haileslassie *et al.*, 2015).

When there was cessation of rainfall during the execution of the experiment, the crop was affected by moisture stress. During this time supplementary irrigate was provided using ground water resource to compensate the amount of water needed by the crop and also to provide the essential moisture for normal growth. This practice helps in alleviating the adverse effects of unfavorable rain patterns and improves crop yields. Therefore, amount of irrigation water to supplementto each experimental plot was directed using drip irrigation which was installed in the experimental site, and the amount of water was measured using soil squeezed method to test soil moisture manually by hand.

3.2. Experimental Plant Materials

A total of 36 bread wheat genotypes including four standard checks (Table.1) obtained from the National Wheat Research Program specifically from Werer (WARC) and Kulumsa (KARC) Agricultural Research Centers. The genotypes were selected based on adaptation to low moisture stress and classified under lowland types. In this experiment, four released for moisture stress bread wheat varieties were included as standard checks.

Table 1.List and pedigree of the thirtysix bread wheat genotypes including four released varieties

G*	Genotype (Pedigree)	Origin
G1	HUBARA-3*2/SHUHA-4	CIMMYT/ICARDA
G2	Atila-7	CIMMYT/ICARDA
G3	ETBW5535	EIAR/KARC
G4	ETBW5957	EIAR/KARC
G5	ATILA/AWSEQ-4	CIMMYT/ICARDA
G6	FENTALLE (CHECK)	CIMMYT/ICARDA
G7	ADEL-2	CIMMYT/ICARDA
G8	DAJAJ-1//VEE'S'/SAKER'S'	CIMMYT/ICARDA
G9	PASTOR-2/HUBARA-5	CIMMYT/ICARDA
G10	HIDDAB/ATTILA-7	CIMMYT/ICARDA
G11	PASTOR-2/HUBARA-3	CIMMYT/ICARDA
G12	HUBARA-5/ANGI-1	CIMMYT/ICARDA
G13	GAMBO (CHECK)	CIMMYT/ICARDA
G14	ANGI-2/HUBARA-3	CIMMYT/ICARDA
G15	ETBW 5898 (SETII C1)	EIAR/KARC
G16	QAFZAH-2/FERRIUG-2 (SET II C1)	CIMMYT/ICARDA
G17	TAGANA	CIMMYT/ICARDA
G18	JNRB.5/PIFED	CIMMYT/ICARDA
G19	KINGBIRD (CHECK)	EIAR/KARC
G20	OGOLCHO (CHECK)	EIAR/KARC
G21	ETBW5955 SET II C2)	EIAR/KARC
G22	REYNA-28	CIMMYT/ICARDA
G23	ETBW5963(SET II C3)	EIAR/KARC
G24	PRINIA-1//NESMA*2/14-/3/DUCULA	CIMMYT/ICARDA
G25	FRANCOLIN #1/BAJ #1	CMSS09B00490S-099M-099Y-2WGY-0B
G26	KAUZ'S'/FLORKWA1//GOUMRIA-3	CIMMYT/ICARDA
G27	BJY/COC//PRL/BOW/3/BLOYKA-1	CIMMYT/ICARDA
G28	KUBSA	CIMMYT/ICARDA
G29	PBW343*2/KUKUNA//KIRITATI	CIMMYT/ICARDA
G30	HUBARA-2/QAFZAH-21//DOVIN-2	CIMMYT/ICARDA
G31	INQALAB 91*2/TUKURU//WHEAR	CIMMYT/ICARDA
G32	ATILA*2//CHIL/BUC*2/3KUKUNA	CIMMYT/ICARDA
G33	SERI 82/SHUHA'S'//PASTOR-2 (SET I)	CIMMYT/ICARDA
G34	florkwa2/6/saker's'/5/rbs /anza/3/kvz/hys/ymh/tob /4/bow	CIMMYT/ICARDA
G35	katila17/deek2/8vee's'/7/cebeco148/3/ron/cha//nor67/5/hk/38m	CIMMYT/ICARDA
G36	attila 50y//attila/bcn/3/star*3/ musk-3	CIMMYT/ICARDA

Source: G*= genotype code number used in the thesis.

3.3. Experimental Design and Layout

The field experiment was laid out in 6x6 triple Lattice design. The width of 1.2 m and length of 2.5 m and a total 3 m^2 area was allocated for each plot in each incomplete block of replication. Each plot had six rows at the spacing of 20 cm between rows, 0.5 m path between plots, 1 m spacing between sub-blocks (incomplete block) and 1.5 m distance between replications with total area of 19.5 m x 41.6 m. The net plot size of experimental plot was 1 m x 2.5 m (2.5 m^2) since the plants in the two outer most rows were treated as border plants and excluded.

3.4. Land Preparation, Sowing and Management

The experimental field was prepared by using farm tractor plough. It was ploughed two times, the first at the beginning of May the second at the middle of June and the third manually using labor worker during planting in early July 2017.

The full dose of blended fertilizer recommended for the study area are NPSzn (19% N, 38%P: 7% S and 2.5%Zn) at the rate of 100 kg ha^{-1} was applied as band application at planting time under supplemental irrigation. Nitrogen fertilizer in the form of Urea (46% N) at a rate of 150 kg ha^{-1} was applied in two split doses; with half applied two weeks after sowing and remaining half after early booting stage. The seeds (125 kg ha^{-1} rate) were sown by hand drilling in the rows as uniformly as possible. All other necessary field management practices were carried out as per the recommendations.

3.5. Data Collection

Data were collected both on plot and plant bases. The four central rows were used for data collection on plot basis, whereas 10 randomly selected plants from the four central rows of each plot were used for data collection on plant basis. Mean data of the 10 sample plants were used for data analyses.

Data collected on plot and plant basis

Thus,data collected on plot basis were days to heading, days to 90% physiological maturity, grain filling period, thousand kernel weight (g),grain yield plot^{-1}(g plot^{-1}), grain yieldha^{-1}(t ha^{-1}), biomass yields (t ha^{-1}) and Harvest index (HI% while data collected on plant basis for the following characters were recorded on 10 randomly selected plants from each experimental plot. The averages of the ten plants in each experimental plot were used for data analysis. Those data were plant height (cm), number of fertile tillers per plant, kernels per spike, spikelet per spike and spike length (cm).

3.6. Data Analyses

3.6.1. Analysis of variance

The data were subjected to analysis of variance (ANOVA) using SAS statistical software version (9.2) (SAS, 2008) as per the expectations shown on Table 2. The comparison of mean performance of genotypes was done following the significance of mean squares using Duncan's Multiple Range Test (DMRT).

3.6.4. Phenotypic and genotypic correlation coefficient

Phenotypic (r_p) and genotypic (r_g) correlations between two traits were estimated using the formula suggested by Johnson *et al.* (1955) and Singh and Chaudhury (1985).

$$r_p = \frac{P\,\mathrm{cov}_{xy}}{\sqrt{(V_p x . V_p y)}} \qquad r_g = \frac{G\,\mathrm{cov}_{xy}}{\sqrt{(V_g x . V_g y)}}$$

Where:-

rp=Phenotypic correlation coefficient, r_g= Genotypic correlation coefficient, $Pcov_{xy}$ =Phenotypic covariance between variables x and y, $Gcov_{xy}$ = Genotypic covariance between variables x and y, V_px = Phenotypic variance of variable x, V_gx = Genotypic variance of variable x, V_py = Phenotypic variance of variable y and V_gy = Genotypic variance of variable y. The calculated phenotypic correlation coefficients values were tested for significance using t-test:t = r_{ph}/SE (r_p)

Where, r_p = Phenotypic correlation; SE (r_p) = Standard error of phenotypic correlation obtained using the following formula (Sharma, 1998).

$$SE (r_p) = \sqrt{\frac{1 - r2\,ph}{n - 2}}$$

Where, n is the number of genotypes tested, r^2_p is phenotypic correlation coefficient.

The coefficients of correlations at genotypic levels were tested for their significance by the formula described by Robertson (1959) as indicated below:

$t = r_{gxy}/SEr_{gxy}$The calculated "t" was compared with the tabulated "t" value at (n-2) degree of freedom at 5% level of significance. Where, n is number of genotypes.

$$SEr_{gxy} = \sqrt{\frac{1 - r2gxy}{h2x}.h2y}$$

Where, h^2x = Heritability of trait x ,h^2y = Heritability of trait y

3.6.5. Path coefficient analysis

Based on genotypic and phenotypic correlations, path coefficient analysis which refers to the estimation of direct and indirect effects of the seed yield attributing characters (independent characters) on seed yield (dependent character) was calculated based on the method used by Dewey and Lu (1959) as follows:

rij = Pij + Σrikpkj where,rij = mutual association between the independent character (i) and dependent character (j) as measured by the genotypic and phenotypic correlation coefficients.Pij = direct effects of the independent character (i) on the dependent variable (j) as measured by the genotypic path coefficients, and

Σrikpkj = Summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k).

The residual effect, which determines how best the causal factors account for the variability of the dependent factor yield, was computed using the formula;$1=p^2R + \Sigma$ p ijrij, Where, p^2R is the residual effect.pijrij = the product of direct effect of any variable and its correlation coefficient with yield i.e.Residual effect = $\sqrt{1-R2}$, where $R^2 = \sum Pijrij$

4. RESULTS AND DISCUSSION

4.4. Phenotypic and Genotypic Correlation Coefficient

4.4.1. Correlation of grain yield with other characters

Number of fertile tillers per plant and harvest index both at phenotypic and genotypic levels had positive and highly significant correlation with grain yield. In addition, at phenotypic level, plant height, biomass yield, spike length and number of kernels per spike had positive and significant correlation with grain yield (Table 5). Therefore, selection of genotypes with high mean values for these traits along with high grain yield seems important rather than selection for yield alone. Selection of genotypes for high yield alone is difficult because yield is the end product of components of several characteristics and has polygenic inheritance and highly influenced by environment and genotype x environment interaction. Therefore, understanding the association of other traits with yield and selection of genotypes for yield and for traits that have significant correlation with yield is important. The analysis of the relationship among these characters and their association with seed yield is essential to establish selection criteria (Singh *et al.*, 1990).

In agreement with these results, Dawit *et al.* (2012) and Obsa (2014) found that at genotypic level, grain yield per hectare showed positive and highly significant association with harvest index and biological yield. At phenotypic level, Dawit *et al.* (2012) and Baranwal *et al.* (2012) reported that 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.

Grain yield showed negative and significant association with days to heading, days to maturity and grain filling period both at phenotypic and genotypic levels (Table 5). The negative correlation of these traits with grain yield suggested that as genotypes were selected for delayed heading, days to maturity and grain filling results selection of genotypes for low yield. This result is consistent with the results reported by Basazen and Getachew (2014) where the correlation grain yield had with days to heading and days to maturity were significant and negative in lines of the man-made crop, triticale (x.*triticosecale* wittmak**)** at both phenotypic and genotypic levels. Adhiena (2016) also reportednegative and significant correlation of grain yield with days to heading and indicated that the negative association of the trait may be due to late set of rainfall in the study area. Similarly, in this study, there was shortage of rainfall in the study area at the end of the cropping season (Table 5). Ahmadi *et al.* (2012) also revealed negative phenotypic correlation of grain yield with days to heading in bread wheat genotypes tested in moisture deficit condition.

Baranwal *et al.* (2012) reported that highly significant and positive correlation of yield per plot with days to heading. These contrasting results might be due to the differences of genotypes used and the environments where the genotypes were evaluated at optimum in which late heading genotypes may be favored for grain yield. The negative and positive significant correlation of grain yield with days to maturity at genotypic and phenotypic levels, respectively, might indicated that genotypic correlation could not be estimated from phenotypic correlation. Phenotypic correlation is the net result of genetic and environmental correlation; therefore, this dual nature makes it clear that the magnitude of genetic correlation cannot be determined from phenotypic correlation (Anwar *et al.*, 2009).

4.4.2. Estimates of correlation among other characters

At phenotypic and genotypic levels, biomass yield had positive and highly significant correlation with plant height,days to heading, days to maturity and number of spikelets per spike but significant positive with kernels per spike (Table 5). Characters like plant height and days to heading werehighly and positively correlated phenotypically and genotypically with spike lengthand number of spikelets per spike.Plant height had positive and highly significant with days to heading while it exhibited positive and significant correlation with days to maturity genotypically and phenotypically. At both levels, days to headingshowed positive and highly significant with days to maturity. Highly positive significant genotypic and phenotypic associations of plant height and days to maturity were noticedwith number of kernels per spike and number of spikelets per spikerespectively. Phenotypic association of grain filling period with days to maturity showed positive and highly significant. Fertile tillers per plant and spike length showed positive and highly significant association with harvest index and number of spikelets per spike at both levels respectively. This result suggests that selection of genotypes for high biomass yield might increase with those traits. That is, the larger biomass yield is the result of increment in plant height. The result also indicated that spike length and kernels per spike increases as a result of significantly higher spikelets per spike for early heading and maturing genotypes as related to shortage of rain fall at end of growing season. This result also showed that number of fertile tillers per plant and spike length maybe given chiefrank for its improvementof grain yield.

Similar finding reported by Alemu *et al.* (2016) that plant height showed significant positive correlation with above ground biomass at both genotypic and phenotypic levels. Significant positive phenotypic association of plant height with spike length, biological yield, tillers per m^2 and grains also were founded by Wasif *et al.*(2015). These findings are also in line with the findings of Ajmal *et al.* (2013) with respect to showing that the number of spikelets per spike showed a significant positive relation with spike length. Awale *et al.* (2013) and Obsa (2014) were reported highly significant association of days to heading with days to maturity and spikelets per spike. Alemu *et al.* (2016) 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 Adhiena*et al.*(2016).Ajmal *et al.* (2013) reported that negative associations of days to maturity with plant height and spike length. At genotypiclevel,negative relationship of number of spikelets per spike with spike length were also found by Khokhar *et al.*(2010).

Number of fertile tiller per plant had positive and highly significant phenotypic correlation with thousand-kernel weight (Table 5). Spike length and number of spikelets per spike showed positive and highly significant phenotypic correlation with number of kernels per spike. At genotypic level, the coefficient of correlation for fertile tiller per plant, spike length and number of spikelets per spike were showed positive significant with thousand-kernel weight and number of kernels per spike respectively. Spike length exhibited positive and highly significant phenotypic correlation with days to maturity. In line with this result, Dergicho *et al.* (2015) stated that positive significant associations were observed for spike length with number of kernels spike^{-1} at genotypic level.Number of tillers per plantpositively associated with 1000 seed weight (Kumar *et al*., 2013).In contrast, spike length had significantly negative genotypic correlation only with days to 50% maturity (Anwar *et al*., 2009).The Spike length also showed non-significant negative associations with days to maturity at phenotypic (Birhanu *et al*., 2017).

Table 5.Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for twelve traits of thirty six bread wheat genotypes

Traits	PH	HD	GFP	MD	FTPP	SL	SPS	KPS	TKW	GY	BY	HI
PH	1.00	0.48**	-0.26	0.34*	-0.14	0.66**	0.46**	0.58**	0.28	0.22	0.54**	-0.15
HD	0.29**	1.00	-0.11	0.91**	-0.57**	0.51**	0.70**	0.23	-0.33*	-0.36*	0.61**	-0.72**
GFP	-0.12	-0.13	1.00	0.32	-0.22	-0.18	0.10	-0.03	0.06	-0.40*	0.05	-0.38*
MD	0.21*	0.88**	0.37**	1.00	-0.64**	0.41*	0.71**	0.21	-0.29	-0.52**	0.60**	-0.85**
FTPP	-0.09	-0.48**	-0.17	-0.53**	1.00	-0.31	-0.52**	-0.13	0.41*	0.53**	-0.16	0.58**
SL	0.49**	0.45**	-0.17	0.34**	-0.22*	1.00	0.57**	0.39*	-0.32	0.07	0.32	-0.17
SPS	0.27**	0.58**	0.09	0.59**	-0.37**	0.52**	1.00	0.37*	-0.26	-0.20	0.46**	-0.50**
KPS	0.40**	0.18	-0.05	0.14	-0.09	0.35**	0.39**	1.00	-0.26	0.30	0.38*	0.00
TKW	-0.19	-0.26**	0.07	-0.21*	0.27**	-0.22*	-0.15	-0.15	1.00	0.18	-0.09	0.23
GY	0.23*	-0.31**	-0.29**	-0.43**	0.41**	0.41**	0.10	0.28**	0.14	1.00	0.20	0.78**
BY	0.41**	0.50**	0.07	0.48**	-0.05	-0.24**	0.46**	0.38*	-0.09	0.31**	1.00	-0.45**
HI	-0.11	-0.66**	-0.31**	-0.77**	0.42**	-0.12	-0.50**	0.00	0.23	0.70**	-0.46**	1.00

*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, SL=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}, HI=Harvest index.

4.5. Path Coefficient Analysis

Path coefficient analysis measures the direct and indirect contribution of independent variables on dependent variables and thus helps breeder in determining the yield components and understanding cause of association between two variables (Baranwal *et al*., 2012). 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 the other that had significant correlation of twelve characters were selected as casual variable. The results of path analysis for direct and indirect effects of the characters studied both at genotypic and phenotypic level are illustrated in (Table 6 and 7).

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

Phenotypic path coefficient analysis showed that harvest index followed by biomass yield days to heading and grain filling period exerted highest positive direct effect on grain yield and harvest index and biomass had positive highly significant phenotypic correlation (Table 6).Likewise, number of kernels per spike, spike length and fertile tiller per plant exerted positive and small magnitude of direct effect but with positive and highly significant phenotypic association with grain yield. From the correlation and path analysis of this experiment harvest index and biomass yield could be considered as main components for selection for grain yield in a wheat breeding program. The low direct effect of number of kernels per spike, spike length and fertile tiller per plant and their highly significant phenotypic correlation with grain yield was due to the cumulative indirect effect of these traits through other. This means even if their direct effect on grain yield is small still improvement of these traits may favor on grain yield.

In most of the previous studies, biological yield and harvest index had positive direct effect on the grain yield. Accordingly, this result agrees with the findings of Alemu *et al.*(2016) and Dawit *et al.* (2012) 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 Berhanu (2004) who reported that biological yield and harvest index were also the most important traits directly affecting grain yield phenotypically. Under drought condition, Abderrahmane *et al*. (2013), 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 number of spikes per plantand number of grains per spike exerted insignificant direct effects on grain yield. The result is disagreeing with Kumar *et al*. (2013) who reportedthe 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 indexso that the direct selection for this trait to improve yield was undesirable.

However, days to maturity which had negative highly significant correlation exerted strongly negative direct effect phenotypic ally. As a result, selection of high yielding genotypes with a fewer days to maturity can be suitable for the study area. Whereas, plant height had negligible negative direct effect however, it had positive significant correlations on grain yield. Hence, the positive phenotypic correlation coefficient of plant height with grain yield was due to the indirect effect. So, its indirect effects should be considered for selection.

These results are in line with Majumder *et al*. (2008),the character days to maturity had negative direct effect on grain yield, which suggests that the selection for early maturing lines with high yield is possible and the influence of plant height on grain yield was negligible. The result is in accordance with Kumar *et al*. (2013), the direct effect of days to maturity was negative and moderate on grain yield. However, the result is contradicts with the results of Anwar *et al.* (2009) and Khokhar *et al.* (2010) showing positive direct effects of days to maturity on grain yield and with the suggestion of more days to maturity would be important selection criteria for improved grain yield plant^{-1} in the breeding material studied. Kumar *et al*. (2013) reported that the highest positive direct effect plant height on grain yield. Low positive direct effect was exhibited by plant height and number of kernel per spike (Alemu *e al*., 2016).

Harvest index and fertile tillers per plant exerted positive considerable indirect effect via days to maturity while these traits exhibited strong negative indirect effect through days to heading and biomass yield (Table 6). The indirect effect of fertile tillers per plant through harvest index on grain yield was moderately negative. Traits like spike length, number of kernels per spike and biomass yield exerted considerable positive indirect effect via days to heading while they exerted negative through days to maturity at phenotypic level. In addition, spike length and number of kernels per spike exerted moderate positive indirect effect on grain yield throughbiomass yield.Moderate positive indirect effect exerted by days to maturity and days to heading through biomass yield but they exhibited strong negative indirect effect via harvest index. Grain filling period also exerted moderate negative indirect effect through days to maturity and harvest index. Days to heading exerted strong negative indirect effect through days to maturity and harvest index while it exerted moderately positive indirect effect through biomass yield. The considerable positive indirect effect exerted on grain yield by plant height through days to heading and biomass yield at phenotypic level. The result suggested that traits like spike length, number of fertile tiller per plant and biomass yield caused increasing of grain yield indirectly.This result agree with the finding of Ali *et al*. (2008) who reported thatthe indirect effect of plant height *via* number of productive tillers per plant negative and high with sugation that the selection for this trait will not be effective.

The indirect effect of biomass through days to heading (0.351), days to maturity (-0.390) and harvest index (-0.470) counter balanced the direct effect of biomass on grain yield and reduced the correlation coefficient to (0.31). 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 (-0.487) days to maturity (0.624) and biomass (-0.355) counter balanced the direct effect of harvest index (1.019) on grain yield. The indirect effect of spike length through days to heading (0.328) and biomass yield (0.485), counter balanced the direct effect of spike length (0.037) on grain yield and reduced the correlation coefficient to 0.41. Therefore, whenever selection is made for improved grain yield, all these characters should be considered.

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 (Singh *et al*, 1990). The residual effect in the present study was 0.0426 (Table 6), showing that 95.74% of the variability in grain yield was explained by the component factors. The remaining 4.26% 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 6. Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of different traits on grain yield at phenotypic level in thirty six bread wheat genotypes evaluated at Mehoni in 2017

Traits	PH	HD	GFP	MD	FTPP	SL	KPS	BY	HI	Rp
Plant height (cm) (PH)	**-0.006**	0.213	-0.045	-0.172	-0.002	0.018	0.021	0.319	-0.112	0.23*
Days to heading (HD)	-0.001	**0.733**	-0.043	-0.710	-0.010	0.017	0.009	0.369	-0.677	-0.31**
Grain filling period (GFP)	0.001	-0.085	**0.371**	-0.302	-0.003	-0.006	-0.003	0.056	-0.320	-0.29**
Days to maturity (MD)	-0.001	0.644	0.138	**-0.809**	-0.011	0.012	0.007	0.371	-0.787	-0.43**
Fertile tillers/plant (FTPP)	0.000	-0.352	-0.062	0.429	**0.021**	-0.008	-0.005	-0.041	0.434	0.41**
Spike length (cm) (SL)	-0.003	0.328	-0.062	-0.272	-0.005	**0.037**	0.018	0.485	-0.125	0.41**
No. of kernels/ spike (KPS)	-0.002	0.131	-0.021	-0.113	-0.002	0.013	**0.052**	0.204	0.019	0.28**
Biomass yield (kg/plot^{-1})	-0.002	0.351	0.027	-0.390	-0.001	0.009	0.014	**0.769**	-0.470	0.31**
Harvest index (HI)	0.000	-0.487	-0.117	0.624	0.009	-0.004	0.001	-0.355	**1.019**	0.70**

Residual = 0.0426, *and**, significant at $P<0.05$ and $P<0.01$, respectively and rp=phenotypic correlation.

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

The maximum positive genotypic direct effect on grain yield was exerted by harvest index followed days to maturity and fertile tiller per plant and aloha highly significant positive genotypic correlations (Table 7).The result indicated that the positive and highly significant correlation of harvest index and fertile tiller per plant with grain yield at genotypic level was due to the direct effect of these characters on grain yield. Hence, harvest index and more number of tillers per plant should be considered in further selection procedures for higher grain yield.

The positive genotypic direct effect for harvest index on grain yield in bread wheat were reported by many authors (Obsa, 2014; Dergicho *et al.*, 2015; Alemu *et al.*, 2016; Berhanu *et al.*, 2017).The harvest index and productive tiller per plant had direct effect and positive significant association with grain yield and suggested that the true relationship between these traits and grain yield. As a result, it was important for selection in a breeding program for higher grain yield (Dergicho *et al.*, 2015). Harvest index (3.33) and productive tillers per plant (1.40) exerted the highest positive direct effect on grain yield and indicated that the main contributors to grain yield (Bhushan *et al*., 2013). On the other hand, the present result is in contradiction to the results of Berhanu (2004); Dawit *et al.* (2012) 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) were showed negligible negative direct effect to the grain yield (Alemu *et al.*, 2016).Fertile tillers per plant had negative direct effect on grain yield per plant with a value of -9.938 (Kashif and Khaliq 2004).The difference may be due to different growing environmental conditions and genotypes used.

The genotypic correlation coefficients of days to heading and grain filling period were significant and negative with grain yield. However, these characters had low negative direct effect on grain yield. This indicates that even if 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 Obsa (2014) who reported negative direct effects of days to heading, grain filling period and thousand-kernel weight on grain yield. Bhushan *et al*. (2013) 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 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 grain filling period 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 strongly positive and negative indirect effect with grain yield through days to maturity and harvest index respectively.

Similar results were also observed by Obsa (2014) that the highest positive indirect effect of days to heading was recorded via days to maturity. Berhanu (2004) also reported that negative indirect effects were exerted by harvest index via days to heading, harvest index via days to maturity on grain yield. The character days to maturity had negative direct effect on grain yield, which suggests that the selection for early maturing lines with high yield is possible (Majumder *et al*., 2008). In contrary to this result Dawit et *al*. (2012)noticed that the highest positive indirect effects on yield were observed for number of tillers per plant, followed by1000 kernel weight, both via days to maturity. This result in part agrees with Khokhar *et al.* (2010) and Solomon and Hanchinal (2013), who indicated that the existence of strong positive correlation and the significantly high magnitude effect of number of tiller per plantwith grain yield through total biomass and harvest index in bread wheat.

The strong indirect effect of harvest index through days to maturity (-0.578) andnumber of tillers per plant (0.145)counter-balanced the positive direct effect of harvest index (1.163) on grain yield and reduced the correlation coefficient to 0.78.Similarly, the considerable indirect effect of number of fertile tiller per plant through days to maturity (-0.432)and harvest index (0.677) were counter-balanced the direct effect of number of fertile tiller per plant (0.250) on grain yield and reduced the correlation coefficient to 0.53. The indirect effect of days to maturity mainly through harvest index (-0.990), number of fertile tiller per plant (-0.159) counter balanced the direct effect of days to maturity on grain yield and reduced the correlation coefficient to (-0.52). 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 Mohammed *et al*. (2011) 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) counterbalanced the direct effect of harvest index on grain yield and reduced the correlation coefficient to (+0.69).

The residual effect was 0.2647 (Table 7), indicating that all the traits included in the study explained high percentage of the variation in grain yield (t ha^{-1}) (73.52%), while other factors not included in the study can explain 26.47%. 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 (0.2647) 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 7. Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of different traits on grain yield at genotypic level in thirty six bread wheat genotypes

Traits	HD	GFP	MD	FTPP	HI	Rg
Days to heading (HD)	**-0.013**	0.012	0.616	-0.142	-0.839	-0.36*
Grain Filling Period (GFP)	0.001	**-0.110**	0.216	-0.056	-0.449	-0.40*
Days to Maturity (MD)	-0.012	-0.035	**0.679**	-0.159	-0.990	-0.52**
Fertile tillers/plant(FTPP)	0.007	0.025	-0.432	**0.250**	0.677	0.53**
Harvest Index (HI)	0.009	0.042	-0.578	0.145	**1.163**	0.78**

Residual = 0.2647, *and**, significant at $P<0.05$ and $P<0.01$, respectively and rg=genotypic correlation.

5. SUMMARY AND CONCLUSIONS

The significant and positive association between grain yield and its components at genotypic and phenotypic level showed that these characters contributed positively towards yield, and emphasis should be given to these traits when selecting for high grain yield. Grain yield was highly significantly and positively correlated with fertile tillers per plant and harvest index both at genotypic and phenotypic levels, and the two traits had also high positive direct effect as well as indirect effects via days to heading and fertile tillers per plant both at genotypic and phenotypic levels. This suggested that the two traits could be used as indirect selection of genotypes for yield. Whereas days to heading, grain filling period and days to maturity had negative and significant correlation with grain yield both at genotypic and phenotypic levels and the former two traits had also negative direct effect on yield at genotypic level. In general, at both genotypic and phenotypic path coefficient analysis on grain yield revealed that positive and direct effect were exerted by harvest index, and fertile tiller per plant. Therefore, selection for high mean values of harvest index and fertile tiller per plant could be considered as the simultaneous selection of genotypes for high gain yield.

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