American Journal of Plant Biology
2022; 7(3): 120-126
http://www.sciencepublishinggroup.com/j/ajpb
doi: 10.11648/j.ajpb.20220703.11
ISSN: 2578-8329 (Print); ISSN: 2578-8337 (Online)

Correlation and Path Coefficient Analysis of Traits in Bread Wheat (*Triticum aestivum* L.) Genotypes Under Drought Stress Conditions

Tamiru Olbana Milkessa

Ethiopian Institute of Agricultural Research, Werer Agricultural Research Center, Addis Ababa, Ethiopia

Email address:
ofiko2006@gmail.com

To cite this article:
Tamiru Olbana Milkessa. Correlation and Path Coefficient Analysis of Traits in Bread Wheat (*Triticum aestivum* L.) Genotypes Under Drought Stress Conditions. *American Journal of Plant Biology*. Vol. 7, No. 3, 2022, pp. 120-126. doi: 10.11648/j.ajpb.20220703.11

Received: July 11, 2022; **Accepted**: August 9, 2022; **Published**: August 24, 2022

Abstract: Seed yield is complex traits considered as ultimate product of it components, hence the knowledge of interrelationship between contributing characters and seed yield is pre-requisite to plan meaningful crop improvement program. A total of 64 bread wheat genotypes were planted at Werer Agricultural Research Center during 2019/20 to assess genotypic and phenotypic correlation coefficients and their direct and indirect effects on grain yield. Under optimum condition biomass yield, harvest index, fertile tiller plant^{-1} and spike length showed positive and highly significant correlation with grain yield at genotypic and phenotypic level. Under stress condition biomass yield, harvest index, fertile tiller plant^{-1}, number of spikelets spike^{-1} and spike length showed positive and highly significant correlation with grain yield at genotypic and phenotypic level. This positive correlation could be resulted from the presence of common genetic elements that controls the characters to the same direction. Under optimum condition, biomass yield (0.864) followed by harvest index (0.627) exerted the highest positive direct effect on grain yield at genotypic level. At phenotypic level biomass yield (0.819) followed by harvest index (0.626) exerted strong positive direct effect on grain yield. Under stress condition biomass yield (0.784) and harvest index (0.405) exerted highest positive direct effect on grain yield. Biomass yield (0.765) exerted positive and highest direct effect on grain yield, whereas harvest index (0.214) exerted moderate positive direct effect on grain yield at phenotypic level under stress condition. The result indicates any genetic improvement on those traits could improve grain yield.

Keywords: Bread Wheat, Correlation, Path Coefficient, Stress

1. Introduction

Bread wheat (*Triticum aestivum* L.) is one of important staple crop produced worldwide including Ethiopia. In Ethiopia it is produced in highland and lowland irrigated areas where the community used it as main source of food. It approximately accounts 20% of nutritional sources for the people around the world [20]. Wheat provides nearly 55% of carbohydrates, 20% of the daily protein and 21% calories for about 40% of the global population [21]. Wheat grain is used in Ethiopia in the preparation of wide range of traditional products like; staple pancake ("*injera*"), bread ("*dabo*"), local beer ("*tella*"), and several other local food items [6].

Despite its food, feed and economic importance, the productivity of wheat in Ethiopia is low (2.97t ha^{-1}) as compared to world yield average [15]. The average yield is low as compared to world yield average; this is mainly due to abiotic stress in addition to biotic stress (rust, septoria, etc). Recurrent drought is the leading abiotic stress causing reduced production and productivity of wheat especially in the low altitude regions of Ethiopia [1]. It can achieve yield loss of 17 to 70% in wheat [5] which results in great economic loss for the farming community [7].

Improvement of a targeted trait cannot be achieved by direct selection of targeted trait but also indirect selection via other traits that are more heritable and ease to select. This selection strategy requires understanding the interrelationship of the characters among themselves and with the other character. The association among traits can be measured by genotypic and/or phenotypic coefficients of correlation. Correlation coefficient analysis may not provide the exact relative importance of direct and indirect influence of each of yield components on grain yield. Path coefficient analysis measures the direct and indirect contribution of independent variables on dependent variables and thus helps breeder understanding cause of association between two variables [13]. In path coefficient analysis, grain yield is considered as dependent variable and the remaining traits are considered as independent variables [27]. The scales for path coefficients was determined in rice with values 0.00 to 0.09 as negligible, 0.10 to 0.19 low, 0.20 to 0.29 moderate and 0.30 to 0.99 high path coefficients [23]. Therefore, the present study was to assess the correlation between agronomic and morphological traits and their direct and indirect effect on grain yield of bread wheat under normal and stress condition.

2. Materials and Methods

2.1. Experimental Site

The study was conducted at Werer agricultural research field during 2019/20. Werer is located 9°27' N and 40°15' E and the altitude of 740m.a.s.l. The mean maximum and minimum temperature of the area is 34°C and 19°C, respectively, and the annual total rainfall in the area is about 571 mm.

2.2. Experimental Treatments and Design

The experiment comprised 62 diverse bread wheat genotypes from International Center of Agriculture for Dry Areas (ICARDA) and 2 local checks. The experiment was laid out in 8*8 simple lattice design with two replications under both normal and stress conditions. Seeds were sown on rows with manual drilling at a rate of 100 kg ha^{-1} basis. The fertilizer application were at a rate of 50 kg ha^{-1} DAP and 100kg ha^{-1} of Urea. Other agronomic practices were applied as per recommendation for wheat in the area.

2.3. Data Collection

Data like days to heading, days to maturity, days to grain filling period, biomass yield, grain yield, 1000 kernel weight, harvest index, fertile tiller per plant, plant height, spikelets spike, spike length and number of kernels spike chlorophyll content and canopy temperature were collected as per descriptor for wheat [19].

2.4. Data Analysis

Genotypic and phenotypic correlation coefficient between all possible pairs of quantitative traits and their direct and indirect effect of the independent variables on grain yield at genotypic and phenotypic level were analysed using SAS version 9.2 [26].

3. Results and Discussions

3.1. Genotypic and Phenotypic Correlation Coefficients

Genotypic correlation coefficient was found to be relatively higher in magnitude than phenotypic correlation coefficient, except in a few cases, which clearly indicated the presence of inherent association among the considered traits. Under optimum condition biomass yield, harvest index, fertile tiller $plant^{-1}$ and spike length showed positive and highly significant correlation with grain yield at genotypic and phenotypic level (Table 1). The positive correlation of these characters with grain yield resulted from the presence of strong coupling linkage of genes or the characters may be the result of pleiotropic genes that control these characters in the same direction. Similar result was previously reported and, selection of genotypes based on high mean values for these traits could be used to improve wheat yield rather than selecting based on yield alone [13, 16, 25, 8, 18]. Grain yield under optimum condition showed negative and significant correlation with days to heading both at genotypic and phenotypic level. The negative correlation of these traits with grain yield suggested that the genotypes should be selected for low days to heading as long days to heading result in yield reduction. Similarly negative and significant correlation of grain yield with days to heading was reported [4].

Under stress condition biomass yield, harvest index, fertile tiller $plant^{-1}$, number of spikelets $spike^{-1}$ and spike length showed positive and highly significant correlation with grain yield at genotypic and phenotypic level (Table 2). Similarly, positive and highly significant correlation of spike length, biomass yield $plant^{-1}$ and harvest index with grain yield was reported [29]. Positive and highly significant correlation of biomass yield $plant^{-1}$, spike length and number of tiller $plant^{-1}$ with grain yield was reported by [9]. Days to maturity showed negative and highly significant correlation with grain yield at genotypic and phenotypic level, indicating that early maturing genotypes had a chance to escape drought stress and thus; early maturing genotypes should be preferred for selection under stress condition. Canopy temperature showed negative and highly significant correlation with grain yield at genotypic and phenotypic level. Negative correlation of grain yield with canopy temperature was reported by [12]. It indicated that elevated canopy temperature accompanied yield reduction under water stress condition; because plants could not maintain adequate transpiration rates [30].

Under optimum condition biomass yield showed positive and highly significant correlation with thousand kernel weight, fertile tiller $plant^{-1}$, spikelets $spike^{-1}$ and spike length at genotypic and phenotypic level. Days to heading showed positive and highly significant correlation with days to maturity and plant height, whereas it showed negative and significant correlation with harvest index and fertile tiller $plant^{-1}$ at both genotypic and phenotypic level. Similar result was previously reported by [8, 2, 10].

Traits like number of spikelets $spike^{-1}$ and spike length under optimum condition showed positive and highly significant correlation with plant height. Similarly, positive association of plant height with spike length and spikelets $spike^{-1}$ was reported [24]. Number of kernels $spike^{-1}$ showed positive and highly significant correlation with number of spikelets $spike^{-1}$, spike length and plant height indicating that tall varieties could produce long spike and more number of spikelets spike^{-1}. Positive and highly significant correlation between spikelets spike^{-1} and number of kernels spike^{-1} was reported by [11].

Under stress condition biomass yield showed positive and highly significant correlation with fertile tiller plant^{-1}, spikelets spike^{-1} and spike length at both genotypic and phenotypic level. Positive and highly significant correlation of biomass yield plant^{-1} with fertile tiller plant^{-1}, spikelets spike^{-1} and spike length at both genotypic and phenotypic level was reported by [9]. Days to maturity exhibited positive and highly significant correlation with Days to heading at both genotypic and phenotypic level. Strong positive correlation between days to maturity and days to heading was reported by [2]. Harvest index exhibited positive and highly significant correlation with fertile tiller plant^{-1} at both genotypic and phenotypic level. Similarly, positive and highly significant correlation with fertile tiller plant^{-1} at phenotypic level was reported previously by [27]. Number of spikelets spike^{-1} and spike length in stressed condition showed positive and highly significant correlation with plant height at phenotypic level. Number of spikelets spike^{-1} showed positive and highly significant correlation with spike length and number of kernels spike^{-1} at genotypic and phenotypic level. Significant and positive correlation of spikelets spike^{-1} with number of kernels spike^{-1} was reported by [29].

Table 1. *Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for twelve traits of 64 bread wheat genotypes under optimum condition Werer Agricultural Research Center during 2019/20.*

Traits	DH	DM	GFP	BY	GY	TKW	HI	PH	FTPP	SPP	SL	KPS
DH	1	0.60**	-0.07	-0.10	-0.22*	-0.04	-0.22*	0.36**	-0.24*	-0.21	0.03	0.09
DM	0.56**	1	0.74**	0.08	0.03	0.05	-0.07	0.39**	-0.03	0.17	0.18	0.04
GFP	-0.06	0.71**	1	0.22	0.30*	0.095	-0.09	0.18	0.21	0.22*	0.22*	-0.03
BY	-0.08	0.04	0.20*	1	0.78**	0.54**	-0.24*	0.18	0.45**	0.20	0.30**	0.02
GY	-0.20*	0.02	0.28**	0.76**	1	0.17	0.38**	0.06	0.30**	0.19	0.28**	0.09
TKW	0.02	-0.04	0.06	0.22*	0.28**	1	0.09	0.25	-0.40	-0.45**	-0.43**	-0.09
HI	-0.18*	-0.03	-0.06	-0.21*	0.43**	0.12	1	-0.18	-0.22*	-0.20*	-0.17*	-0.27*
PH	0.26**	0.35**	0.22**	0.16	0.07	0.22**	-0.10	1	0.08	0.24**	0.39**	0.01
FTPP	-0.21*	-0.03	0.19	0.45**	0.30**	0.12	-0.20*	-0.001	1	-0.16	-0.06	-0.01
SPP	-0.01	0.06	0.20*	0.28*	0.22**	0.20	-0.18*	0.26**	-0.12	1	0.61**	0.18
SL	0.01	0.16	0.22*	0.29*	0.30**	0.12	-0.15*	0.43**	-0.06	0.43**	1	0.27*
KPS	0.05	0.019	0.06	0.02	0.11	-0.12	-0.22*	0.14	0.04	0.52**	0.38**	1

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

Table 2. *Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for fourteen traits of 64 bread wheat genotypes under stress condition at Werer Agricultural Research Center during 2019/20.*

Traits	DH	DM	GFP	BY	GY	TKW	HI	PH	FTPP	SPP	SL	KPS	CHC	CT
DH	1	0.52**	-0.07	0.22	-0.17	0.14	-0.038	0.05	-0.04	0.37**	0.17	0.24*	0.09	-0.12
DM	0.42**	1	0.30*	-0.34**	-0.39**	0.15	-0.32*	-0.02	-0.47**	0.24	0.006	0.09	0.11	-0.23
GFP	-0.12	0.33**	1	0.03	-0.13	0.18	0.29*	0.14	0.09	0.17	0.18	0.004	0.12	0.001
BY	0.14*	-0.28**	0.05	1	0.92**	0.07	0.20	0.09	0.51**	0.37**	0.43**	0.28*	0.14	-0.46**
GY	-0.13	-0.36**	-0.15	0.88**	1	0.15	0.56**	0.13	0.60**	0.26**	0.35**	0.17	0.17	-0.54**
TKW	0.13	0.13	0.17	0.06	0.11	1	0.19	0.21	-0.04	0.03	0.22	0.01	0.09	-0.23
HI	-0.12	-0.30**	0.24	0.17	0.34**	0.14	1	0.11	0.46**	-0.13	-0.03	-0.19	0.17	-0.34**
PH	0.03	-0.11	0.09	0.09	0.16	0.17*	0.13	1	0.12	0.31*	0.31*	0.08	-0.25*	-0.28*
FTPP	-0.07	-0.39**	-0.11	0.38**	0.51**	-0.02	0.45**	0.18*	1	-0.10	0.02	-0.10	0.02	-0.12
SPP	0.35**	0.11	0.10	0.35**	0.24**	0.03	-0.18*	0.29**	-0.12	1	0.39**	0.66**	-0.09	-0.33**
SL	0.16	0.04	0.18*	0.39**	0.31**	0.18*	-0.10	0.27**	-0.10	0.39**	1	0.37**	-0.02	-0.21
KPS	0.23**	0.08	0.012	0.26**	0.16	0.02	-0.17*	0.09	-0.11**	0.64**	0.42**	1	0.06	-0.19
CHC	0.10	0.19*	0.19*	0.12	0.12	0.06	-0.01	-0.24**	-0.02	-0.05	0.04	0.07	1	0.01
CT	-0.12	-0.15	-0.05	-0.43**	-0.48**	-0.21**	-0.14	-0.25**	0.11	-0.26**	-0.20*	-0.15	-0.05	1

*and**, significant at *P≤0.05* and *P≤0.01*, respectively. DH=days to heading (days), DM=days to maturity (days), GFP=grain filling period (days), BY=biomass yield (t ha-1), GY=grain yield (t ha-1), TKW= Thousand-kernel weight, HI=Harvest index, PH=plant height, FTPP=fertile tiller plant-1, SPS=Spikelets spike-1, SL=Spike length (cm), KPS= number of kernels spike-1, CHC=chlorophyll content and CT=canopy temperature (°C).

3.2. Genotypic Direct and Indirect Effects of Other Traits on Grain Yield Under Optimum Condition

Path coefficient analysis measures the direct and indirect contribution of independent variables on dependent variables and thus helps breeder understanding cause of association between two variables [13]. When the traits having direct positive effect on grain yield is selected for further improvement, the indirect one must be considered as they have association with those characters in another way.

Under optimum condition, biomass yield (0.864) followed by harvest index (0.627) exerted the highest positive direct effect on grain yield (Table 3). Highest positive direct of harvest index and biomass yield on grain yield was reported [8]. Grain filling period exerted positive and small magnitude of direct effect on grain yield. This indicates that even if indirect effects of this (grain filling period) on grain yield through other characters were small its cumulative effect could be the cause for significant and positive correlation. Positive direct effect of grain filling period on grain yield was reported by [10]. Fertile tiller plant^{-1} (0.034) and spike length (0.10) exerted negligible positive direct effect on grain yield (Table 3); however they had positive and highly significant correlation with grain yield due to the indirect effect exerted through other traits. Therefore when selection is target to improve these traits, their indirect effect with other traits should be considered wisely.

The indirect effects of all traits *via* other traits on grain yield were negligible except for biomass yield and harvest index. Positive indirect effect was exerted by fertile tiller plant^{-1} and spike length *via* biomass yield. Moderate negative indirect effect was exerted by harvest index *via* biomass yield. Moderate negative indirect effect of harvest index *via* biomass yield on grain yield was previously reported by [10]. Biomass yield and fertile tiller plant^{-1} exerted negative indirect effect on grain yield *via* harvest index. The indirect effect of biomass yield *via* harvest index (-0.150) counter balanced the direct effect of biomass yield (0.864) and reduced the correlation coefficient to 0.78. Harvest index also exerted negative indirect effect (-0.207) *via* biomass yield which counter balanced the direct effect of harvest index (0.627) and reduced correlation to 0.38. The indirect effect of fertile tiller plant^{-1} mainly through biomass yield (0.389) and harvest index (-0.138) counter balanced the positive direct effect of fertile tiller plant^{-1} (0.034) on grain yield and reduced the correlation coefficient to 0.30. This indicated that the correlation they had with grain yield is not only due to the direct effect but also the indirect effect exerted *via* other traits. The residual effect was 0.1145, indicating that all the traits included in the study explained high percentage of variation in grain yield (t ha^{-1}) (88.55%), while other factors not included in the study can explain 11.45%.

Table 3. *Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of different traits on grain yield at genotypic level in 64 bread wheat genotypes evaluated at Werer Agricultural Research Center during 2019/20 under optimum condition.*

Traits	DH	GFP	BY	HI	FTPP	SL	r_g
DH	0.018	-0.010	-0.086	-0.138	-0.008	0.003	-0.22*
GFP	-0.001	0.146	0.190	-0.056	0.007	0.022	0.30*
BY	-0.002	0.032	0.864	-0.150	0.015	0.030	0.78**
HI	-0.004	-0.013	-0.207	0.627	-0.007	-0.017	0.38**
FTPP	-0.004	0.031	0.389	-0.138	0.034	-0.006	0.30**
SL	0.001	0.032	0.259	-0.107	-0.002	0.100	0.28**

*and**, significant at *P<0.05* and *P<0.01* respectively, rg=genotypic correlation, DH= days to heading, GFP=Grain filling period, BY= Biomass yield, HI= harvest index, FTPP= fertile tiller plant-1, SL= spike length and Residual=0.1145.

Table 4. *Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of different traits on grain yield at genotypic level in 64 bread wheat genotypes evaluated at Werer Agricultural Research Center during 2019/20 under stress condition.*

Traits	DM	BY	HI	FTPP	SPP	SL	CT	r_g
DM	0.001	-0.266	-0.135	-0.008	0.013	0.001	0.006	-0.39**
BY	0.000	0.784	0.081	0.009	0.02	0.046	-0.012	0.92**
HI	0.000	0.157	0.405	0.008	-0.007	-0.003	0.009	0.56**
FTPP	-0.001	0.400	0.186	0.018	-0.005	0.002	0.003	0.60**
SPS	0.000	0.281	-0.053	-0.028	0.054	0.004	0.0088	0.26**
SL	0.000	0.337	-0.012	0.000	0.021	0.011	0.005	0.35**
CT	0.000	-0.365	-0.138	-0.002	0.018	-0.026	-0.025	-0.54**

*and**, significant at *P<0.05* and *P<0.01* respectively, rg=genotypic correlation, DM= days to maturity, BY= Biomass yield, HI= harvest index, SPS= Spikelets spike-1, SL= spike length, CT= Canopy temperature and Residual=0.135.

3.3. Genotypic Direct and Indirect Effects of Other Traits on Grain Yield Under Stress Condition

Under stress condition biomass yield (0.784) and harvest index (0.405) exerted highest positive direct effect on grain yield (Table 4). Days to maturity, fertile tiller plant^{-1}, spikelets spike^{-1} and spike length exerted small magnitude of positive direct effect on grain yield. Similar findings were reported for biomass yield and harvest index on grain yield under water deficit in bread wheat [9, 2]. Canopy temperature exerted negative direct effect on grain yield. Negative direct effect of canopy temperature with grain yield in bread wheat and it could also be used as differentiating trait for the selection of best surviving genotypes under drought condition [22]. Fertile tiller plant^{-1} (0.018), spike length (0.054) and number of spikelets spike^{-1} (0.011) exerted positive indirect effect on grain yield *via* biomass yield. Positive indirect effect of spike length and number of spikelets spike^{-1} *via* biomass yield in bread wheat under drought condition was reported by [9]. Considerable amount of negative indirect effect was exerted on grain yield by days to maturity *via* harvest index and positive indirect effect was exerted by fertile tiller plant^{-1} *via* harvest index. Positive indirect effect of fertile tiller plant^{-1} on grain yield *via* harvest index was reported by [27]. The residual effect was 0.1355 indicating that all the traits included in the study explained high percentage of variation in grain yield (t ha^{-1}) (86.45%), while other factors not included in the study can explain

13.55%. So that, yield components used in the experiment were good.

3.4. Phenotypic Direct and Indirect Effects of Other Traits on Grain Yield Under Optimum Condition

Phenotypic path analysis revealed that biomass yield (0.819) followed by harvest index (0.626) exerted strong positive direct effect on grain yield (Table 5). Grain filling period (0.125) and thousand kernel weight (0.115) exerted small magnitude of positive direct effect on grain yield. Above ground biomass and harvest index exerted positive direct effect on grain yield and concluded that these characters are good indicator for grain yield improvement in bread wheat [3]. Positive direct effect of thousand kernel weight on grain yield was reported by [8, 17]. Positive and negligible direct effect was exerted by fertile tiller plant^{-1}, spikelets spike^{-1} and spike length on grain yield. Similarly, positive and negligible direct effect of number of spikelets spike^{-1} and spike length was previously reported by [14].

The indirect effect of all traits on grain yield *via* other traits was weak and negligible except biomass yield and harvest index. However, each components of grain yield showed considerable amount of indirect effects *via* other traits like biomass yield and harvest index in both negative and positive directions. The residual effect was 0.1453, indicating that all the traits included in the study explained high percentage of variation in grain yield (t ha^{-1}) (85.47%), while other factors not included in the study can explain 14.53%.

Table 5. *Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of different traits on grain yield at phenotypic level for 64 bread wheat genotypes evaluated at Werer Agricultural Research Center during 2019/20 under optimum condition.*

Traits	DH	GFP	BY	HI	FTPP	TKW	SL	SPS	r_p
DH	*-0.027*	-0.007	-0.066	-0.113	-0.007	0.001	0.001	-0.003	-0.22*
GFP	0.002	*0.125*	0.164	-0.038	0.007	0.023	0.002	0.004	0.28**
BY	0.002	0.025	*0.819*	-0.131	0.016	0.032	0.007	-0.005	0.76**
HI	0.005	-0.007	-0.172	*0.626*	-0.007	-0.017	0.003	-0.003	0.43**
FTPP	0.006	0.024	0.369	-0.125	*0.035*	-0.007	0.004	0.002	0.30**
TKW	0.000	0.025	0.229	-0.094	-0.002	*0.115*	0.004	0.008	0.28*
SL	-0.001	0.007	0.180	0.063	0.004	0.014	*0.032*	0.004	0.30**
SPS	0.004	0.025	0.229	-0.113	0.004	0.049	0.006	*0.019*	0.22**

*and** significant at *P<0.05* and *P<0.01*, respectively, rp=phenotypic correlation, DH= days to heading, GFP=Grain filling period, BY= Biomass yield, TKW= Thousand kernel weight, HI= harvest index, FTPP=fertile tiller plant-1, SL= spike length, SPS= spikelets spike-1 and Residual=0.1453.

Table 6. *Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of different traits on grain yield at phenotypic level for 64 bread wheat genotypes evaluated at Werer Agricultural Research Center during 2019/20 under stress condition.*

Traits	DM	BY	HI	FTPP	SPS	CT	r_p
DM	*-0.102*	-0.214	-0.064	-0.026	-0.003	0.038	-0.36**
BY	0.028	*0.765*	0.036	0.026	-0.08	0.109	0.88**
HI	0.031	0.135	*0.218*	0.03	0.004	0.061	0.48**
FTPP	0.048	0.299	0.098	*0.068*	0.068	-0.029	0.56**
SPS	-0.015	0.268	-0.038	-0.02	*-0.022*	0.066	0.24*
CT	0.015	-0.229	-0.059	-0.009	0.06	*-0.254*	-0.48**

*and**, significant at P<0.05 and P<0.01, respectively, rp=phenotypic correlation, DM= days to maturity, BY= Biomass yield, HI=Harvest index, FTPP= fertile tiller plant-1, SPS= Spikelets spike-1, CT= Canopy temperature and residual=0.2326.

3.5. Phenotypic Direct and Indirect Effects of Other Traits on Grain Yield Under Stress Condition

Phenotypic path analysis revealed that biomass yield (0.765) exerted positive and highest direct effect on grain yield, whereas harvest index (0.214) exerted moderate positive direct effect on grain yield (Table 6). Fertile tiller plant^{-1} (0.068) exerted negligible positive direct effect on grain yield. Days to maturity, number of spikelets spike^{-1} and canopy temperature exerted negative direct effects on grain yield. Similar to the present result, positive direct effect of fertile tiller plant^{-1} on grain yield was reported by [27]. The negative direct effect of canopy temperature on grain yield was reported by the author in bread wheat under drought stress condition. Negative direct effect of days to maturity on grain yield was reported previously by [2]. In contrast positive direct effect of number of spikelets spike^{-1} on grain yield was reported by [9].

Number of fertile tiller plant^{-1} and number of spikelets spike^{-1} exerted moderate positive indirect effects on grain yield *via* biomass yield. Canopy temperature and days to maturity exerted considerable amount of negative indirect effect on grain yield *via* biomass yield. The positive indirect effect of number of spikelets spike^{-1} on grain yield *via* biomass yield plant^{-1} was reported previously by [9] The residual effect was 0.2313, indicating that all the traits included in the study explained high percentage of variation in grain yield (t ha^{-1}) (76.87%), while other factors not included in the study can explain 23.13%. It also gives a clue to go further study to find rest of traits contributed the rest of variation on grain yield.

4. Conclusions

Genotypic correlation coefficient was found to be relatively higher in magnitude than their corresponding phenotypic correlation coefficient, except in a few cases, which clearly indicated the presence of inherent association among considered traits. The minimum value of direct and indirect phenotypic effect of majority of polygenic traits on grain yield observed in the present study indicated that genetic manipulations of bread wheat accessions for several quantitative characters are more important to improve the productivity of wheat than management practices. Generally, quantitative characters having genetically positive direct effect on grain yield should be given due attention when collection or selection of landraces/genotypes is made.

Conflicts of Interest

The author declares that they have no competing interests.

Acknowledgements

Ethiopian Institute of Agricultural Research was acknowledged for financial support for the research work.

References

[1] Abate GT, Bernard T, Brauw AD, Minot N (2018). The impact of the use of new technologies on farmers' wheat yield in Ethiopia: evidence from a randomized control trial. Journal of Agriculture and Economics, 49: 409–421.

[2] Abd-Allah HT, Rabie HA, Mansour E, Swelam AA (2018). Genetic variation and interrelationships among agronomic traits in bread wheat genotypes under water deficit and normal irrigation conditions. Zagazig Journal Agricultural Research, 45 (4): 1209-1229.

[3] Abderrahmane H, Abidine F, Hamenna B (2013). Correlation, path analysis and stepwise regression in durum wheat (Triticum durumDesf) under rainfed conditions. Journal of Agriculture and Sustainability, 3 (2): 122–131.

[4] Adhiena Mesele, Wassu Mohammed and Tadesse Dessalegn (2016). Estimation of heritability and genetic advance of yield and yield related traits in bread wheat (*Triticum aestivum* L.) genotypes at Ofla district, Northern Ethiopia. International Journal of Plant Breeding and Genetics, 10 (1): 31-37.

[5] Ahmadizadeh M, Shahbazi H, Valizadeh M, Zaefizadeh M (2011). Genetic diversity of durum wheat landraces using multivariate analysis under normal irrigation and drought stress conditions. African Journal of Agricultural Research, 6 (10): 2294-2302.

[6] Akililu Nigussie, Adem Kedir, Abiy Adisu, Getinet Belay, Desta Gebrie Kidane Desalegn (2015). Bread wheat production in small scale irrigation user's agro-pastoral households in Ethiopia: case of Afar and Oromia regional state. Journal of Development and Agricultural Economics, 7 (4): 123-130.

[7] Akpinar BA, Lucas SJ, Budak H (2013). Genomics approaches for crop improvement against abiotic stress. The Scientific World Journal, doi: 10.1155/2013/361921.

[8] Alemu Dabi, Firew Mekbib, Tadesse Desalegn (2016). Estimation of genetic and phenotypic correlation coefficients and path analysis of yield and yield contributing traits of bread wheat (*Triticum aestivum* L.) genotypes. International Journal of Natural Resource Ecology and Management, 1 (4): 145-154.

[9] Arya S, Mishra DK, Bornare SS (2013). Screening genetic variability in advance lines for drought tolerance of bread wheat (*Triticum aestivum* L.). International Journal of Quarterly Life Sciences, 8 (4): 1193-1196.

[10] Ashebir Baye, Baye Berihun, Muluken Bantayehu, Bitwoded Derebe (2020) Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) lines. Cogent Food and Agriculture, 6 (1): 1752603.

[11] Athar H, Bhutto Asghar A, Rajpar SH, Ali K, Amjad A (2016) Correlation and regression analysis for yield traits in wheat (*Triticum aestivum* L.) genotypes. Journal of Natural Sciences, 8 (3): 96-104.

[12] Bahar B, Yildirim M, Yucel C (2011). Heat and drought resistance criteria in spring bread wheat (*Triticum aestivum* L.): Morpho-physiological parameters for heat tolerance. Scientific Research and Essays, 6 (10): 2212-2220.

[13] Baranwal DK, Mishra VK, Vishwakarma MK, Yadav PS, Arun B (2012). Studies on genetic variability, correlation and path analysis for yield and yield contributing traits in wheat (Triticum. aestivum L.). Plant Archives, 12 (1): 99-104.

[14] Birhanu Mecha, Sentayehu Alamerew, Alemayehu Assefa, Ermias Assefa and Dargicho Dutamo (2017). Correlation and path coefficient studies of yield and yield associated traits in bread wheat (*Triticum aestivum* L.) genotypes. Advances in Plants and Agriculture Research, 6 (5): 00226.

[15] CSA (Central Statistical Agency) (2020). Report on area and production of major crops (private peasant holdings, meher season). Agricultural sample survey 2018/2019 central statistics agency: Addis Ababa, Ethiopia.

[16] Dawit Tsegaye, Tadesse Dessalegn, Yigzaw Dessalegn and Getnet Share (2012). Genetic variability, correlation and path analysis in durum wheat germplasm (Triticum durum Desf). Agricultural Research and Reviews, 1 (4): 107-112.

[17] Foud HM (2018). Correlation, path and regression analysis in some bread wheat (*Triticum aestivum* L.) genotypes under normal irrigation and drought condition. Egypt Journal of Agronomy, 40 (2): 133-144.

[18] Girma Degife (2018). Genetic variability, correlation and path coefficient analysis of agro-morphological traits among bread wheat (*Triticum aestivum* L.) genotypes at Raya valley of Southern Tigray, Ethiopia, MSc Thesis Haramaya University, Ethiopia.

[19] IBPGR (International Board for Plant Genetic Resources) (1985). Wheat descriptors. Commission of European community: Committee on disease resistance breeding and use of gene bank, Rome, Italy.

[20] Khabiri E, Imani AA, Shahbazi H (2012). Studying the grain yield and yield components in advanced rain fed wheat genotypes. Annals of Biological Research, 3 (12): 5647-5650.

[21] Khan N, Naqvi FN (2011). Heritability of morphological traits in bread wheat advanced lines under irrigated and non-Irrigated conditions. Asian Journal of Agricultural Sciences, 3 (3): 215-222.

[22] Kumar AV, Singh J, Kumar L, Kumar R., Kumar P, Chand P (2017). Genetic variability and diversity analysis for yield and its components in wheat (*Triticum aestivum* L.). *Indian Journal Agricultural Research,* 51 (2): 128-134.

[23] Lenka D, Mishra B (1973). Path coefficient analysis of yield in rice varieties. Indian Journal of Agricultural Sciences, 43: 376-379.

[24] Morketa Gudeta (2017). Genetic variability and association of traits in bread wheat (*Triticum aestivum* L.) varieties at Gitilo Dale, Western Ethiopia. Msc Thesis Postgraduate Program Directorate, Haramaya University, Ethiopia.

[25] Obsa Chimdesa (2014). Genetic variability among bread wheat (*Triticum Aestivum* L.) genotypes for growth characters, yield and yield components in Bore District, Oromia Regional State. MSc Thesis Haramaya University, Ethiopia.

[26] SAS (Statistical Analysis System) (2008). SAS Institute Version 9.2 Inc. Cary, NC., USA.

[27] Singh KA, Singh SK, Garg HS, Kumar R, Choudhary R (2014). Assessment of relationships and variability of morpho-physiological characters in bread wheat (*Triticum aestivum* L.) under drought stress and irrigated Conditions. The Bioscan, 9 (2): 473-484.

[28] Singh RK, Chaundhary BD (1977). Biometrical Methods in Quantitative Genetic Analysis. Kalyani publishers, New Delhi, p 304.

[29] Subhani GM, Chowdhry MA (2000). Correlation and path coefficient analysis in bread wheat under drought stress and normal conditions. Pakistan Journal of Biological Sciences, 3 (1): 72-77.

[30] Talebi R (2011). Evaluation of chlorophyll content and canopy temperature as indicator for drought tolerance in durum wheat (Triticum durum Desf.). Australian Journal of Basic and Applied Sciences, 5 (11): 1457-1462.