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EVALUATION OF SOME BREAD WHEAT (*TRITICUM AESTIVUM* L.) LANDRACES OF BALOCHISTAN FOR YIELD AND RELATED TRAITS THROUGH CORRELATION AND PATH ANALYSIS

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Abstract

Genetic diversity in wheat landraces is major tool for incorporating desirable alleles in advanced breeding material. In present study we evaluated 54 landraces and 6 commercial varieties collected from different regions of Balochistan. Local landraces of Balochistan are better adapted to drought stress in the region and have some diverse genotypes. In this study agronomic traits were characterized and correlation coefficient and path coefficient were determined for grain yield and other important agronomic traits i.e., plant height, days to 50 % heading, productive tillers 0.5 m-2, spike length, seed number spike-1, 1000 grain weight, biological yield, and harvest index to confirm the association among the traits. According to results, grain yield showed significant positive correlation with all the traits except days to 50 % heading. The correlation of different traits with grain yield under stress condition helps in indirect selection for high yield and can be incorporated in advanced lines to improve stress resistance in advanced germplasm. On average, strong positive correlation was recorded for grain yield with harvest index (0.780) and biological yield (0.748). Path analysis revealed high direct positive effect of HI (0.651) and biological yield (0.619) on grain yield, whereas the number of productive tillers showed low negative direct effect (-0.036) on the grain yield. All other traits showed low positive direct effect on grain yield. Biological yield and harvest index can play significant role in indirect selection while better yielding landraces can be used for genetic improvement of advanced germplasm that lack stress (drought) tolerance as compared to local landraces.

Keywords: *Biological yield, Correlation coefficient, Grain yield, Harvest index, Path analysis, Wheat landraces*

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the leading food grain crops of the world. This grain has carbohydrates (60-80 %), fat (1.5-2.0 %), proteins (8-15 %), inorganic ions (1.5-2.0 %), and small quantity of vitamin B-complex and E (1). In world wheat production is nearly 90% based on common or bread wheat *Triticum aestivum* L., while the remaining 10 % of wheat is based on macaroni or durum wheat *Triticum turgidum* subsp. *durum* (2). Cultivation of wheat occurs on more than 240 million hectares which is more than the area under any other crop. During 2014, worldwide production of wheat was almost 702 million tons (3). With significant position in agriculture policies and as a main food grain of Pakistan, wheat cultivated area in 2013-2014 was 9039 thousand hectares with 25.3 million tones total production (4). To meet the demand of increasing population and for food security, the higher and stable wheat yields is major goal of breeding programs (5). A wheat landrace can be defined as mixture of homozygous genotypes usually shows important genetic variation for quantitative, qualitative, and developmental (phenological) characters (6, 7). Wheat landraces are source of different important genetic alleles which can be utilized in biotic and abiotic stress resistance.

Correlation studies need to be carried out to identify the characters that have positive association with yield and can help in effective genotypic selection. Yield as a quantitative trait is highly influenced by environment and carries genetic variability, breeders usually try to find the traits which are more related to yield but have less influence of environmental conditions. To achieve better grain yield, selection of traits

having higher correlation with grain is considered one of the significant breeding approaches for faster crop improvement (8). Number of researchers have reported the correlation of yield with various parameters. the positive effect was reported on grains spike^{-1}, 1000 kernel weight, biological yield and grain weight on grain yield (9). Positive significant association was found between grain yield, plant height, 1000 kernel weight, flag leaf length and width in drought stress environment (10). Another study (11) reported variation in wheat grain yield due to the traits like 1000 grain weight, length of spike, and spikes m^{-2}. Similarly, (12, 13, 14) found the positive association between grain yield and the characters such as, weight of 1000 grains, spikelet number spike^{-1}, tillers plant^{-1} and length of spike, and recommended that these parameters be used for the progress of plant grain yield. Indirect selection for yield through yield related traits can help in developing genotype which can effectively tolerate the abiotic stresses in multiple environmental conditions and provide stable yield. Path analysis helps in studying the direction and magnitude of correlation of yield with other characters directly or indirectly (15).

Grain yield is major trait for improvement that results by the combination of genetic makeup, environment and genotype with environment interaction. Genotype × environment (GE) interaction is extremely vital as it causes different reactions of genotypes when they are grown in different environments. Information based only on correlation studies may be confusing and not accurate at times. One way for measuring the effect of one variable over others is the path coefficient analysis, which allows the separation of correlation coefficient into its components. In this way total correlation can be divided into direct and indirect effects based on the real information for the involvement of traits, thus providing a basis for improvement in yield through the selection for appropriate characters (16). The use and conservation of landraces conserved in genebank is essential for wheat breeding programs globally (17).

The present study was carried out to evaluate the wheat landraces of Balochistan for grain yield and related characters and to check the association, direct and indirect effect of different traits with grain yield and among different characters for their incorporation in breeding programs.

MATERIALS AND METHODS

This study was conducted at Balochistan Agricultural research and Development Centre, Quetta (BARDC) during 2013-14 cropping season. Total 54 local wheat landraces and 6 check varieties (Shalkot-14, AZRC-2, Tijaban-10, Zardana, Sariab-92 and Raskoh) were evaluated in the experiment under rain fed conditions. Accessions were collected from Plant Genetic Resource Institute, PGRI (NARC), Islamabad. The field experiment was laid out in α lattice design with two replications. Each accession was sown in 2 rows of 5-meter length with row to row distance of 25 cm (Fig. I). Di ammonium phosphate (DAP) and urea fertilizer were applied as per recommended dose (split doses). Wheat accessions were examined for different quantitative characters, i.e., days to 50 % heading, plant height (cm), productive tillers 0.5 m^{-2}, seed number spike^{-1}, spike length (cm), 1000 kernel weight (gm), grain yield (kg ha^{-1}), biological yield, and harvest index (%).

Fig. 1. Wheat landraces at different growth stages at Balochistan Agriculture Research and Development Center, Quetta

The data were tested for descriptive statistics and was subjected to Pearson correlation coefficient by using software Minitab version 17. Path diagram was made by using software SPSS Amos 21 and path coefficient analysis was done by using the method of Dewey and Lu (18). Recorded average temperature and rainfall during the growing season were given in Fig. 2.

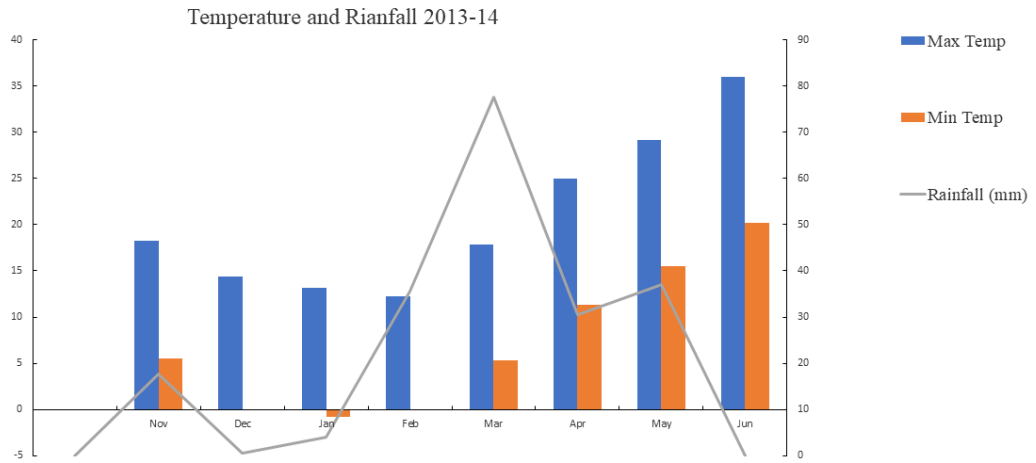

Fig. 2. Average temperature (Minimum and Maximum °C) and rainfall recorded for the wheat landraces during growing season

RESULTS AND DISCUSSION

Wheat landraces are major source of important stress resilient traits and can be incorporated in advance high yielding genotypes that lack high stress tolerance. Summary statistic was applied to measure the mean, standard deviation, maximum and minimum values of all the parameters of the landraces along with commercial varieties (Table I). Mean and standard deviation for grain yield was 1082.1 and 261.4 kg ha^{-1} respectively, while the maximum and minimum values were 1735.0 and 490.0 kg ha^{-1}respectively.

CORRELATION COEFFICIENT

Correlation coefficient among different yield related traits with yield is of major significance and provides a basis for selection of different traits for increasing yield. The Pearson correlation coefficients for total 10 quantitative characters were presented in (Table II).

HARVEST INDEX (%)

Harvest index is the ratio of harvested grain to total above ground dry matter and is very important trait in wheat breeding. Grain yield showed strong significant positive correlation (r=0.78) with harvest index showing high grain yield with increase in harvest index (Table II). The results agreed with (19,14). Moreover, harvest index had high significant positive association with thousand grain weight (0.464), seed number spike^{-1} (0.403) and peduncle length (0.350). All of these traits served as important contributors towards increasing grain yield.

PEDUNCLE LENGTH (CM)

Positive significant correlation was found between grain yield and peduncle length (r=0.380). Results were consistent with Habibpour *et al.*, 2012 and Siahbidi *et al.*, 2013 (20, 21). Peduncle length showed negative non-significant correlation with plant height but highly significant positive association with HI (Table II). This non-significant association is due to genetic variability among wheat genotypes which produce Peduncle with high green area, relationship to spike and high rates of photosynthesis are necessary for grain filling. Peduncle length is positively correlated with the yield of grain, because the collection and remobilization of photosynthetic materials take place in seeds (22). In conditions with scarcity of water the plants peduncle is able to maintain high water content in comparison to the flag leaf (23).

PLANT HEIGHT (CM)

Grain yield had low but positive correlation with plant height (r=0.336). Plant height showed negative association with grains spike^{-1} and significant positive correlation with biological yield indicating. The taller plants are with reduced grain spike^{-1} and increased biological yield (Table II). Our results were in agreement with Sourour *et al*., 2010 (24). According to another study, the areas in Pakistan with minimum rainfall focus should be given to the growth of tall varieties for straw and good yield (25). Positive association was present among TDM, grain yield and plant height and similar results were also observed in a previous study (20) indicated low yield than dwarf varieties but in terminal drought stress environment showed high stable yield (22).

Table I. Descriptive statistics (Mean, Standard deviation, maximum and minimum values) of wheat landraces for different traits

Parameters	Mean	Standard deviation	Minimum	Maximum
GY (Kg ha^{-1})	1082.1	261.4	490.0	1735.0
DTH (50 %)	156.01	4.25	145.00	167.00
Ped. Length (cm)	17.775	5.368	6.000	29.500
PH (cm)	86.18	9.17	59.50	102.50
TDM (Kg ha^{-1})	6800	1045	4800	10000
SPKL (cm)	8.892	1.109	6.500	12.000
TGW (g)	23.263	5.710	12.250	36.600
GPS	31.47	7.94	21.50	57.50
HI %	15.909	2.758	8.756	21.512
Tillers	170.23	37.32	87.00	266.00

GY: Grain yield; DTH: Days to 50 % heading; Ped. Length: Peduncle length; PH: Plant height; TDM: Total dry matter; SPKL: Spike length; TGW: Thousand grain weight; GPS: Grains spike^{-1}; HI: Harvest index; Tillers

Table II. Pearson correlation coefficient of 10 quantitative traits of bread wheat landraces

Variables	GY (kg ha^{-1})	DTH (50 %)	Ped.Length (cm)	PH (cm)	TDM (kg ha^{-1})	SPKL (cm)	TGW (g)	SdNospk	HI (%)
DTH (50 %)	-0.207^{NS}								
Ped.Length (cm)	0.380**	-0.165^{NS}							
PH (cm)	0.336**	-0.358^{NS}	-0.024^{NS}						
TDM (kg ha^{-1})	0.748**	0.008^{NS}	0.226^{NS}	0.435**					
SPKL (cm)	0.112^{NS}	-0.073^{NS}	0.160^{NS}	-0.158^{NS}	0.004^{NS}				
TGW (g)	0.565**	0.157^{NS}	0.199^{NS}	0.069^{NS}	0.388**	0.036^{NS}			
SDSPK	0.360**	-0.171^{NS}	0.171^{NS}	-0.218^{NS}	0.108^{NS}	0.441**	0.135^{NS}		
HI (%)	0.780**	-0.337**	0.350**	0.091^{NS}	0.183^{NS}	0.176^{NS}	0.464**	0.403**	
PRDT	0.277*	-0.294*	0.077^{NS}	0.286*	0.278*	0.027^{NS}	-0.151^{NS}	-0.004^{NS}	0.207^{NS}

GY: Grain yield; DTH: Days to 50 % heading; Ped.Length: Peduncle length; PH: Plant height; TDM: Total dry matter; SPKL: Spike length; TGW: Thousand grain weight; SdNospk: Seed number spike^{-1}; HI: Harvest index; PRDT: Tillers
**= Highly significant at 0.01, *= Significant at 0.05, NS= Non significant

TOTAL DRY MATTER (Kg ha^{-1})

The results for total dry matter showed significant positive correlation with grain yield (r=0.748). Better biomass can efficiently utilize photosynthesis to produce assimilates which results in better sink strength. Our results are in agreement with Peymaninia *et al*., 2012 (26). Early crop vigor and high TDM are vital traits under drought stress as early soil cover can reduce evapotranspiration (ET) from soil and provide increased moisture during early growth.

SPIKE LENGTH (cm)

A non-significant positive correlation was found between grain yield (r=0.112) and spike length (Table II). It is reported by Mohammadi *et al*., 2014 (27) that spike length is indirectly correlated to grain yield by increase in number of grains.

SEED NUMBER SPIKE^{-1}

Seed number per spike is major trait in wheat breeding and highly influenced by environmental conditions. Drought has major impact on grain number specially when terminal drought impacts the crop

during reproductive growth stage. Significant positive correlation was observed between grain yield and seed number spike^{-1} (r=0.360). Seed number spike^{-1} is an important yield contributing trait showed significant positive correlation with spike length (Table II) which indicates that more the length of spike, more seed number spike^{-1} and higher will be the grain yield. As reported by Foulkes *et al*., 2011 (28) seed number carried higher elasticity as compared to grain weight and proved to be highly beneficial in increasing grain yield. seed number and seed mass as components of spike are important traits for improvement and development of seed yield in breeding programs (29).

PRODUCTIVE TILLERS 0.5 m^{-2}

Productive tiller is reported as an important trait which influence total grain yield. In our study we found positive significant correlation (Table II) between grain yield and productive tillers 0.5 m^{-2} (r=0.277). This indicated that more productive tillers result in increased grain yield by producing higher number of grains per m^2. Positive correlation of grain yield was found with productive tillers plant^{-1}, seed number spike^{-1} and spikelet spike^{-1} and as high number of tillers produces more spikelet and higher grain yield (30).

THOUSAND GRAIN WEIGHT (g)

Significant positive correlation was found between grain yield and thousand grain weight (r=0.565). Two of the important traits which can have direct effect on final grain yield is number of seeds and grain weight. Our results were in agreement with Siahbidi *et al*., 2010 (21) who reported higher correlation of thousand grain weight with final grain yield. Thousand grain weight showed highly significant correlation (r=0.464) with harvest index (Table II). The genetic variability for grain weight is lower as compared to seed number as this trait is more elastic than grain weight that promotes seed number (31).

DAYS TO HEADING (50 %)

Negative non-significant correlation (r=-0.207) was found between grain yield and 50 % heading (Table II). Under rain fed conditions good grain yield can be achieved through early maturing genotypes which help in reducing water stress in late stages as reproductive stage is highly influenced by low water availability (32).

PATH ANALYSIS

The purpose of path analysis was to get more information on the association between traits and to partition the correlation coefficient into direct and indirect effects of characters on grain yield. Path analysis is also used to find out the most important and effective traits on grain yield. Grain yield was selected as dependent variable and HI, Peduncle length, TDM, seed number spike^{-1}, plant height, thousand grain weight and productive tillers were selected as independent variables for path analysis. Relatively high positive direct effect over grain yield was recorded by HI (0.651) followed by TDM (0.619) indicate that increase in average HI and TDM will increase the grain yield, while the productive tillers contribute low negative direct effect (-0.036). The rest of traits showed low direct positive effect over grain yield (Fig. 3). Significant and positive correlation of grain yield with spikelet per spike, plant height, and seeds per spike for 30 wheat genotypes was found by Bigyan *et al*., 2025 (33) in farmers field at Golbhatta, Lalitpur. Another study on wheat landraces of Saharan Oasis of Algeria stated positive direct effect of thousand grain weight, and seed number per spike on yield of grain through path analysis (34).

HI VS GRAIN YIELD

The highest positive direct effect (0.651) and significantly higher positive correlation coefficient (0.780) over grain yield was recorded by HI (Table III) which confirmed that increase in grain yield can be achieved directly by increasing harvest index trait defined as the grain yield of a wheat crop expressed as the decimal fraction of aboveground biomass production. The most positive indirect effect of HI by TDM was (0.113), by seed number spike^{-1} was moderately positive (0.012) and by peduncle length, plant height and thousand grain weight was negligible over grain yield, while indirect effect of HI upon grain yield by

productive tillers was negative and low. Grain yield can be maximized up to (20%) by selecting harvest index as main yield related character (35).

TOTAL DRY MATTER VS GRAIN YIELD

According to path analysis results TDM showed high positive direct effect (0.619) as well as high significant positive correlation coefficient (0.748) with grain yield which indicate true relationship. The correlation of TDM with grain yield is almost similar to its direct effect showing true relationship. Total dry matter revealed most indirect positive effect (0.119) via HI on grain yield (Table III).

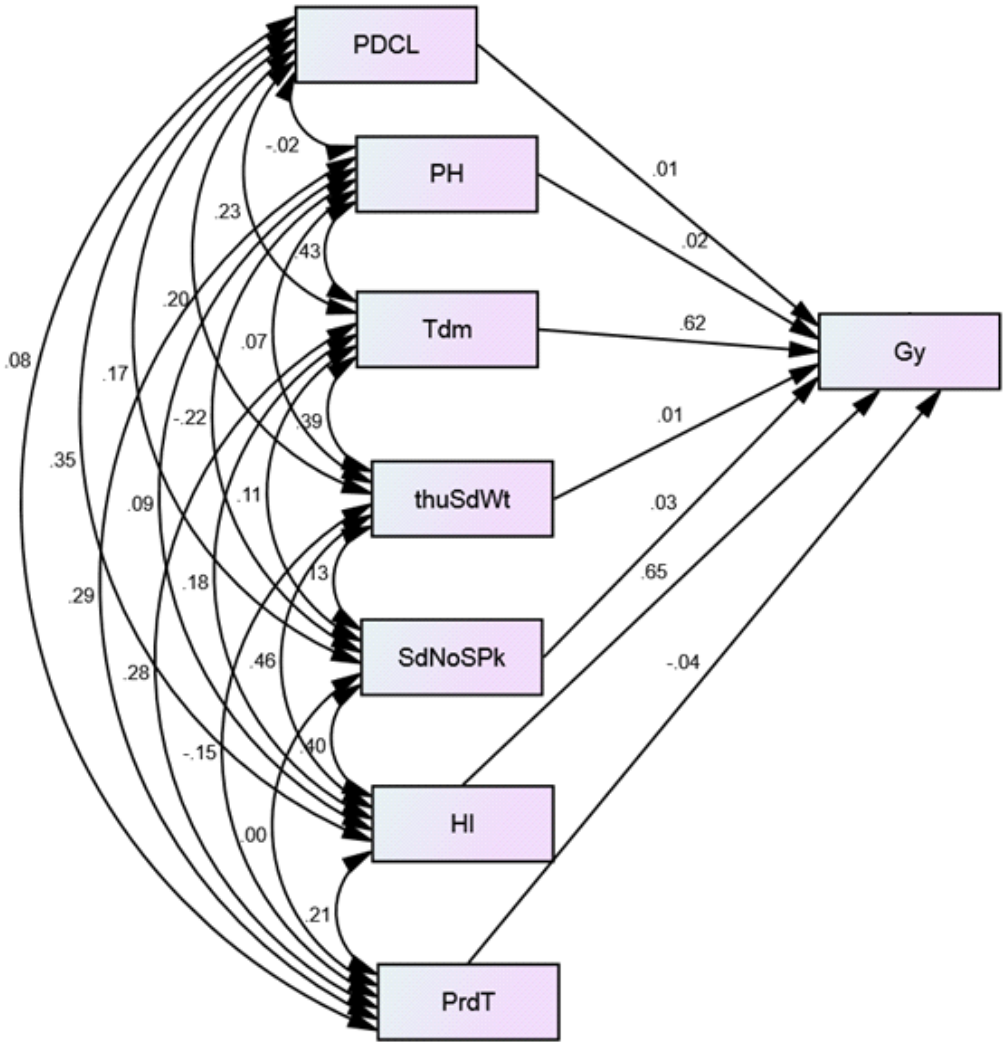

Fig. 3. Path diagram of grain yield with different traits in bread wheat landraces (GY: Grain yield; Ped.Length: Peduncle length; PH: Plant height; TDM: Total dry matter; SPKL: Spike length; ThuSdWt: Thousand seed weight; SdNoSPK: Seed number spike^{-1}; HI: Harvest index; Prdt: Productive Tillers)

THOUSAND GRAIN WEIGHT VS GRAIN YIELD

Direct positive effect of thousand grain weight was observed but had high indirect positive effect by HI (0.302) and TDM (0.241) on grain yield. Although the correlation coefficient of thousand grain weight was significantly high (0.565) but direct effect on grain yield is positive but low (Table III), so this character showed no true relationship and direct selection for improvement of yield. Similar results low positive direct effect of thousand grain weight on grain yield was found by (12), however, most positive direct effect of thousand grain weight on yield of wheat was reported by Peymaninia *et al*., 2012 (26).

SEED NUMBER SPIKE^{-1} AND PEDUNCLE LENGTH VS GRAIN YIELD

The direct effect of seed number spike^{-1} and peduncle length over grain yield was positive and low (0.033 and 0.009) respectively (Table III). Seed number spike^{-1} had high positive indirect effect through HI (0.262). Similarly, peduncle length had most indirect positive effect (0.23) through HI on grain yield. The

correlation coefficient of seed number spike^{-1} and peduncle length was significantly positive (0.360 and 0.380) respectively but the direct effect of these two traits on grain yield was low because of their indirect effect through HI. So, the indirect selection of these two traits via grain yield will be effective. Similar results of seed number spike^{-1} were reported by Cifci, 2012 (36).

Table III. Path analysis of grain yield with related traits of bread wheat landraces

Traits	Direct effect	Indirect effects by							Correlation coefficient with GY
		Ped. Length	PH	TDM	ThuSdWt	SdNoSPK	HI	Prdt	
Ped. Length	0.009	_____	-0.001	0.14	0.002	0.005	0.23	-0.003	0.380**
PH	0.025	0.0002	_____	0.27	0.001	-0.01	0.059	-0.012	0.336**
TDM	0.619	0.002	0.01	_____	0.004	0.003	0.119	-0.011	0.748**
ThuSdWt	0.010	0.002	0.001	0.241	_____	0.004	0.302	0.006	0.565**
SdNoSPK	0.033	0.002	-0.004	0.068	0.001	_____	0.262	0.0002	0.360**
HI	0.651	0.004	0.002	0.113	0.005	0.012	_____	-0.008	0.780**
Prdt	-0.036	0.001	0.005	0.174	-0.002	-0.0001	0.137	_____	0.277**

GY: Grain yield; Ped.Length: Peduncle length; PH: Plant height; TDM: Total dry matter; ThuSdWt: Thousand seed weight; SdNoSPK: Seed number spike^{-1}; HI: Harvest index; Prdt: Productive Tillers

PLANT HEIGHT VS GRAIN YIELD

The positive direct effect of plant height on grain yield is low (0.025), while its correlation coefficient was (0.336). The direct positive effect of plant height on grain yield was indicated by (36). The positive indirect effect of plant height via TDM was high (0.27) and was (0.059) for HI but by seed number spike^{-1} and productive tillers was negative (-0.01 and -0.012) respectively (Table III).

PRODUCTIVE TILLERS VS GRAIN YIELD

Productive tillers showed low negative direct effect (-0.036) on grain yield (Table III) and results agreed with the findings (37). This was because of indirect positive effect of TDM (0.174) and HI (0.137).

CONCLUSION

The selection of genotypes with high grain yield is significant to recognize the association of different traits with grain yield and the interrelationship among selected traits as well. Correlation coefficient between yield and related traits of wheat landraces of Balochistan concluded that harvest index, biological yield, thousand grain weight, plant height, peduncle length, spike length and seed number spike^{-1} were considerable traits which are correlated positively with grain yield. Harvest index is correlated with thousand grain weight and biological yield is correlated with plant height and productive tillers that perform function in the improvement of grain yield. The strongest correlation of grain yield was found with harvest index and biological yield that show improved grain yield with improvement of these characters. Due to correlation improvement among traits can be achieved implicitly by the selection of one of the characters. According to path analysis HI and biological yield had most direct effect with seed yield and all the traits revealed indirect effect on yield mostly via these two characters, consequently both of these traits were mainly responsible for improvement of grain yield of wheat. Among all the traits thousand grain weight showed no true relationship with grain yield, because correlation coefficient of this trait was high but direct effect on grain yield was positive and low. Therefore, the landraces and genotypes with high harvest index and high biological yield aid to the development of high yielding varieties.

Conflict of interest:

There is no conflict of interest in this study.

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Authors' contribution:

PSJ Performed the experiments, analyzed the data, wrote the manuscript; JK Provided technical outputs and lab facilities; RD Assistance in analysis of data.

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