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Contribution of Spike-Related Traits for Grain Yield in Spring Wheat

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Abstract

World population is increasing day by day with an exponential rate while cultivated land area is decreasing. Such an immense increase in human population requires more food per unit area. This can only be achieved by producing high yielding crop varieties. Current experimental study was conducted at Research area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad to disclose relationship between different spike-related traits and grain yield. The experimental material was comprised of 47 spring wheat genotypes including 35 approved varieties and 12 elite wheat lines. The experiment was conducted in Randomized Complete Block Design with three replications. At maturity, data were collected for plant height, tillers per plot, grain filling period, spike length, spikelets per spike, spike density, spike weight, thousand grain weight, grain weight per spike, number of grains per spike, harvest index, biological yield and grain yield per plot. Results revealed that number of tillers per meter, spike weight, thousand grain weight, grain weight per spike, harvest index and biological yield per meter had a positive and significant relationship with grain yield at both genotypic and phenotypic level. Path analysis showed that the direct effects of plant height, number of tillers per meter, thousand grain weight, grain weight per spike and number of grains per spike were negative. Biplot analysis revealed that thousand grain weight, spike weight and biological yield could be used as selection criteria. The results suggested that spike weight, harvest index and biological yield could be used as selection criteria while selecting high yielding genotypes for future use in hybridization programs. Promising wheat line, PB9881 performed best among studied genotypes and could be released as commercial variety. FD83, Punjab-11 and PB9881 could be used in future breeding programs for improvement in grain yield.

Keywords: Genotypic Correlation, Path analysis, Biplot analysis**,** Selection criteria

Introduction

World population is increasing day-by-day with an exponential ratio. Currently world population is nearly 7.43 billion which is projected to be reached to 9.7 billion USD in 2050 (United Nation, 2015). At the same time, world arable land area is becoming scarcer to be used for crop production due to intensive urbanization, land degradation and use of agricultural land for non-agricultural uses. It is important to note that world's arable land per person had reduced to about 48% from 0.45ha in 1961/63 to 0.22ha in 2006 (FAOSTAT, 2017). This alarming situation demands more food per unit area, which can be achieved by managing crop production and improving the genetic makeup of food crops for better productivity.

Wheat is the most widely grown food crop in the world. It contains more protein contents as compare to any other cereal crop as its grain contains 8-15 % protein (Shewry, 2009). It was grown on an area of 224.97 million hectares and 735.25 million metric Tons production was obtained in 2016 in all over the world (USDA, 2017). About 35% people in world use wheat as their staple food (IDRC, 2017). Any adverse change or reduction in wheat production will ultimately affect 1/3rd of the world's population. In Pakistan, it was grown on an area of 9.26 million ha and 25.48 million tons produce was obtained with an average yield of 2.75 metric tons per ha. (Govt. of Pakistan, 2015-16). Grain yield per hectare of wheat in Pakistan (2.73 tons/ha) is very low as compared to other wheat growing countries like China (5.39 tons/ha), Mexico (4.55 tons/ha), Ukraine (3.83 tons/ha), Canada (3.25 tons/ha), European Union (3.02 tons/ha) and United State (2.93 tons/ha) (USDA, 2017). The reasons for low grain yield are poor management practices, high input prices, diseases and insects attack and less availability of highly adoptive cultivars. So, there is an utmost need of improved varieties with high adoptability.

The ultimate goal of wheat breeding is to produce high yielding cultivars. As wheat yield is a polygenic trait, it is highly influenced by environmental conditions, so it is unjustified to select genotypes on the basis of grain yield.

Selection of genotypes should be based upon yield related traits like number of tillers per plant, 1000-seed weight and other spike characteristics that are less affected by adverse environmental conditions. The correlation with path coefficient analysis not only measures the relationship between different traits but also measures the direct and indirect effects of traits on grain yield. Tazeen *et al.*, (2009) reported that number of grains per spike and spike length were the main contributor toward higher grain yield. Vahid *et al.*, (2011) investigated that biological yield of plant has significantly positive and direct effect on yield while number of grain per spike and thousand grain weight had significant direct effect in negative direction on grain yield in wheat. The effect of number of grains per spike, grain weight per spike and 1000-grain weight on yield was indirect but significant and positive. Rameez *et al.*, (2012) investigated that spike related traits i.e. spike length, spikelets per spike, number of grains per spike and thousand grain weight had significantly positive association with improved grain yield in wheat. The current study was conducted to explore the contribution of spike related traits in wheat improvement.

Materials and Methods

The experimental material was comprised of forty-seven spring wheat genotypes, including thirty-five varieties and twelve advance wheat lines (Table 1). Wheat varieties were obtained from Ayub Agriculture Research Institute (AARI) and National Agriculture Research Council (NARC) while advance wheat lines were obtained from Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experiment was conducted at Plant Breeding Research Area, University of Agriculture, Faisalabad during 2016-17 under Randomized Complete Block Design (RCBD) Followed with three replications. Seeds were sown with the help of hand-driven drill in rows, each 3-meter long and 30 cm apart from other row.

At maturity, data was recorded for various plant traits including spike related traits i.e. Plant height (PH), No. of tillers per meter (Tillers), grain filling period (GFP), spike length (SL), spikelets per spike (SS), spike density (SD), spike weight (SW), thousand grain weight (TGW), grain weight per spike (GWS), number of grains per spike (NGS), harvest index (HI), biological yield per meter (BY) and grain yield per meter (GY). Statistical significance of data was ascertained by analysis of variance (Steel *et al.*, 1997 while genotypic and phenotypic correlation coefficients were determined as suggested by Kown and Torrie (1964) and Path analysis was performed according to Dewey and Lu (1959). Three statistical Softwares *i.e.* XLSTAT 16.0, Statistix 8.1 and R 3.3.2 were used to analyze the data.

Results and Discussion

The analysis of variance showed highly significant differences among wheat genotypes for grain yield and spike related traits for all characters under study (Table 2). Genotypic and phenotypic correlation coefficients tell us about the magnitude effects of genotype on a particular trait. Furthermore, phenotypic correlation also tells about the influence of environment on a particular plant trait. Lesser the difference between genotypic and phenotypic correlation, more stable the plant trait. The association of spike related traits with grain yield was estimated by genotypic and phenotypic correlation coefficients (Table 3). Grain yield had positive and significant genotypic correlation with plant height (0.2577*****), number of tillers (0.2210*****), spike weight (0.6769******), thousand grain weight (0.5203******), number of grains per spike (0.4972******), grain weight per spike (0.2923******), harvest index (0.3650**) and biological yield (0.6456**). Similarly, it had significantly positive phenotypic correlation with all above characters except plant height (0.1849^{NS}) and number of grains per spike (0.1927^{NS}) which were non-significant. Higher phenotypic correlation for tillers per meter (0.3839), biological yield per meter (0.7544) and harvest index (0.4050) than genotypic correlation coefficients suggest that these traits were highly affected by environment. So, selection on the basis of these traits is not a sensible approach. Similar results were reported by Khaliq *et al.*, 2004; Desheva, 2016; Nukasani, 2013; Mohibullah, 2011 and Waqar-Ul-Haq, 2010). On the other hand, spike weight, thousand grain weight and grain weight per spike are also highly and positively correlated with grain yield at both levels but their genotypic correlation coefficient values are much higher than environmental correlation coefficients, which suggest that environment had very little influence on these traits. So, these traits could be used in parental selection for wheat improvement breeding programs.

Similarly, biological yield had highly significant positive genotypic and phenotypic correlation with plant height, number of tillers, spike length, spike weight, grain weight per spike and number of grains per spike however significantly negative associations were observed with harvest index. Plant height exhibited significant and positive correlation with grain filling period, spike length, spikelets per spike, spike weight, grain weight per spike, number of grains per spike and biological yield at both genotypic and phenotypic levels. Grain filling period showed positive and significant relationship with plant height and spike length. Spike length revealed significant and positive associations with plant height, grain filling period, spikelets per spike and number of grains per spike at phenotypic and genotypic levels however negative correlations were observed for number of tillers and spike density. Moreover, highly significant positive relationship was detected for spike weight, grain weight per spike and biological yield at only genotypic level. Our results were in agreement with Nukasani, (2013), Jameel and Ali, (2008), Desheva, (2016), Waqar-Ul-Haq, (2010).

Spikelets per spike had positive and significant phenotypic and genotypic correlation with plant height, spike length and grain weight per spike while negative association was detected with number of tillers per meter. Significantly negative relationship was observed between spike density and spike length at both levels. Highest positive genotypic correlation was observed between spike weight and grain weight per spike (0.8816**) while highest negative association was observed between spike length and spike density (-0.5415). Detected between grain weight per spike and spike weight (r_g= 0.8816**) while highest negative correlation was observed between spike density and spike length (r_g = -0.5415**).

Path Analysis

Correlation coefficient analysis alone is not enough to precisely select plant parameters for grain yield improvement. Path analysis provides reliable estimates for direct and indirect sources of correlation. The direct effect of biological yield to grain yield (0.9508) was highest followed by harvest index (0.8173) and spike weight (0.2815) in positive direction, respectively. However, spikelets per spike (-0.2106), thousand grain weight (-0.1216), grain weight per spike (-0.0667), number of grains per spike (-0.0609), plant height (-0.0485) and number of tillers per meter (-0.01426) had direct negative effects on grain yield yet these effects were very low in magnitudes (Muhammad *et al.*, 2006, Ali and Shokar, 2012; Fellahi *et al.*, 2013, Ata *et al.*, 2014 and Khokhar *et al.,* 2010).

Plant height had positive indirect effect via biological yield (0.3386) while negative effects via spikelets per spike (-0.1008) and harvest index (-0.0568) on grain yield. Number of tillers per meter had negative direct effects (-0.01426) on grain yield. Number of tillers had positive indirect effects on grain yield via biological yield (0.4076) while negative effects through harvest index (-0.1993). Highest negative indirect effects were observed in harvest index via biological yield (-0.4745) followed by biological yield via harvest index (-0.3856) and spike density via biological yield (-0.2042) on grain yield. The effects of most of the traits via spike density, spikelets per spike, plant height, number of grains per spike and thousand grain weight were negative with low magnitude. Highest positive indirect effects were contributed by spike weight, tillers per meter and grain weight per spike via biological yield 0.4380, 0.4076 and 0.3663, respectively. Grain yield was positively correlated by most of the traits via harvest index and biological yield.

Path analysis depicted another side of picture than correlation. In genotypic correlation, plant height, number of tillers per meter, spike weight, thousand grain weight and grain weight per spike had a positive correlation with grain yield. However, path analysis explored that these traits had direct negative influence on grain yield per meter. The direct negative effects of these traits were masked by the high positive indirect effects through biological yield per meter. Similarly, spike densityhad negative genotypic correlation with grain yield but path analysis revealed that it had direct positive effect on grain yield which was masked by high negative indirect effect via biological yield. It is evident from Fig. 3 that plant biomass is directly related to final grain yield. Maximum grain yield was observed in advance wheat line, PB9881 (233kg/plot) followed by FD-83 (212 Kg/plot) and Punjab-2011 (211kh/plot) while Chakwal-86 (112 Kg/plot) gave minimum grain yield followed by Pak-81 (122 Kg/plot) and PB9882 (124 Kg/plot). On the other hand, Maximum biomass was produced by GA-2002 (602.9 Kg/plot) followed by Kohistan-97 (571.3 Kg/plot) and Sehar-2006 (537 Kg/plot) whereas minimum biomass was produced by Punjab-85 (304 Kg/plot) followed by Pak-81 (311 Kg/plot)

Biplot Analysis

Principal Component biplot analysis is used to represent the variation among different factors and also to construct relationship between these factors. Biplot 1 was drawn between Principal component 1 and 2, which accounts for 46.8% variations in the data. Biplot 1 showed a close relationship between grain yield and biological yield, 1000-grain weight, spike weight and grain weight per spike. However, spike density, being on the opposite direction to grain yield, had a negative association with grain yield. It further showed that most of the genotypes reside near the of biplot, showing that their performance is near to overall average of all genotypes. However, genotypes PBW-222 (35), Fareed-2006 (20), PB-85 (4), Chakwal-86 (5), PB-9881 (46) and Kohistan-97 (27) remained at maximum distance from base of the plot depicting that these genotypes had maximum variations for studied traits. Biplot 2 contribute 45.39% variations in the data and showed a strong correlation of grain yield with plant height, number of grains per spike and spike length. Same genotypes showed maximum variability in biplot 2 along with Iqbal-2000, FD-83 and Shahkar-95. The magnitude of spike density was more in biplot 2 than biplot 1 whereas magnitude of tillers per meter and spikelets per spike was more in biplot 1.

Conclusion: The study revealed that improvement of wheat crop for grain yield could only be made by selecting and hybridizing appropriate parents on the basis of their diversity, genotypic correlation and path analysis. Advance wheat line, PB9881 performed best among studied genotypes and could be used for commercial release. FD83, Punjab-11 and PB9881 could also be used in future breeding programs for improvement in grain yield.

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Table 1. Name of Genotypes under Study

Sr. No	Genotypes	Sr. No	Genotypes	Sr. No	Genotypes
1	FD-85	17	Ufaq-2002	**33**	Pak-81
2	Kohnoor-83	18	SH-2002	**34**	PITIC-62
3	FD-83	**19**	Manthar-03	**35**	PBW-222
4	PB-85	**20**	Farid-2006	**36**	PB-9757
5	Chakwal-86	**21**	Sehar-06	**37**	PB-9751
6	Rawal-87	**22**	Lasani-2008	**38**	PB-9750
7	Inqlab-91	**23**	Chakwal-50	**39**	PB-9746
8	Watan-93	**24**	Miraj-2008	**40**	PB-9744
9	Parwaz-94	**25**	Ass-11	**41**	PB-9742
10	Shahkar-95	**26**	Glaxy-13	**42**	PB-9718
11	PB-96	**27**	Kohistan-97	**43**	PB-9708
12	MH-97	**28**	Iqbal-2000	**44**	PB-9887
13	Chenab-2000	**29**	Punjab-11	**45**	PB-9882
14	Uqab-2000	**30**	AARI-11	**46**	PB-9881
15	AS-2002	**31**	Millet-2011	**47**	PB-9880
16	GA-2002	**32**	Barani-83		

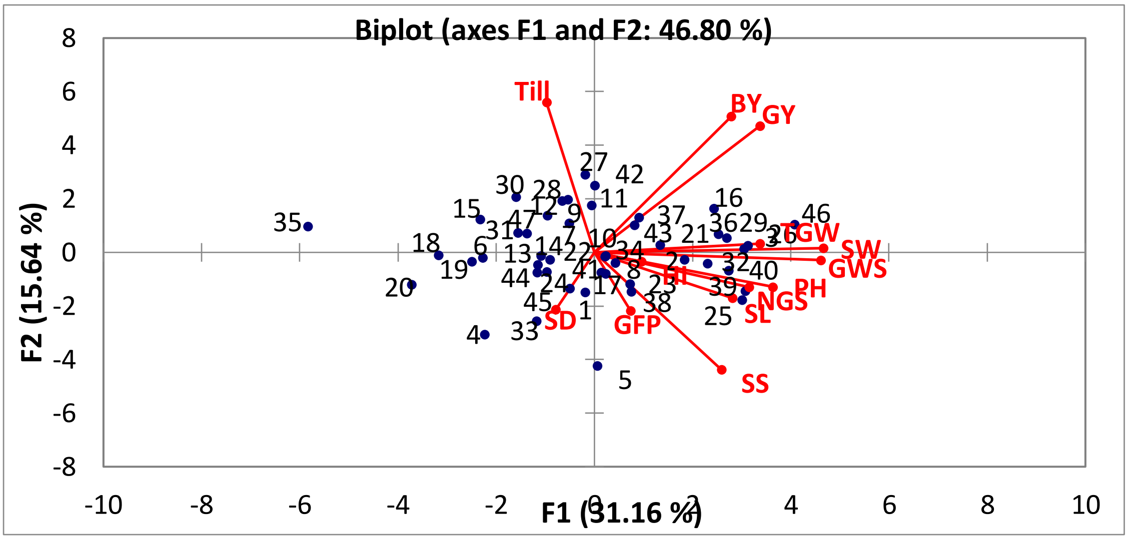

Figure 1 Biplot 1 between PC1 and PC2 for traits and genotypic comparison

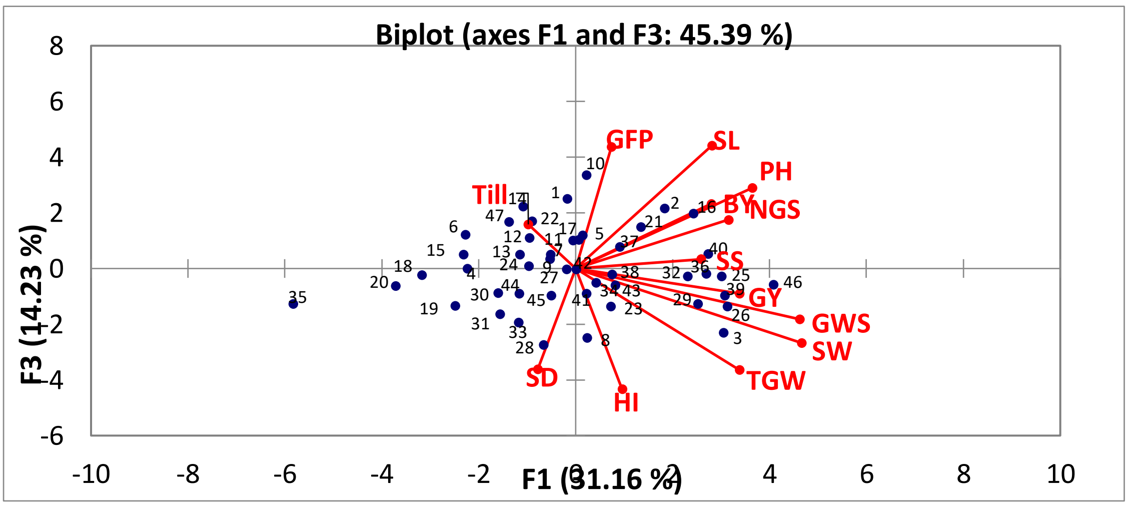

Figure 2 Biplot 2 between PC1 and PC3 for traits and genotypic comparison

Table 2. Analysis of Variance (ANOVA) for 13 spike related traits in Bread Wheat

SOV	df	Mean Squares												
		PH	Till	GFP	SL	SS	SD	SW	TGW	GWS	NGS	HI	BY	GY
Replications	2	15.456*	396.68	2.333	5.569	0.921	0.026	0.182	6.507	0.173	7.145**	2.633	6278.5	1264.26
Genotypes	35	236.22**	1772.43**	52.47**	7.63**	12.36**	0.106**	0.94**	75.78**	0.566**	230.20**	62.44**	14574.9**	2158.78**
Error	70	4.761	223.60	1.457	3.251	0.604	0.016	0.084	11.97	0.071	1.75	7.98	3000.4	598.74
CV %		2.024	11.55	3.162	14.16	3.758	7.792	9.55	8.99	12.49	2.66	7.55	12.15	14.58
Heritability (B.S)		94%	69%	92%	31%	86%	64%	77%	64%	70%	97%	69%	56%	46%

* Significant at 5%, ** Highly significant at 1%, NS= Non-significant, PH: Plant height (cm), Till: Tillers per meter, GFP: Grain filling period, SL: Spike length (cm), SS: Spikelets per spike, SD: Spike density, SW: Spike weight (g), TGW: Thousand grain weight (g), GWS: Grain weight per spike (g), NGS: Number of grains per spike, HI: Harvest index, BY: Biological Yield (g/m) and GY: Grain yield (g/m)

Table 3. Direct (Bold) and Indirect Effects of Spike-Related traits on Grain Yield in Bread Wheat

Traits	PH	Till	GFP	SL	SS	SD	SW	TGW	GWS	NGS	HI	BY
PH	**-0.04845**	0.00303	0.02711	0.07918	-0.10078	-0.01906	-0.04040	-0.02033	-0.03176	-0.02840	-0.05679	0.33856
Tillers	0.01031	**-0.01426**	-0.00372	-0.06368	0.07149	0.01858	-0.06369	0.03644	0.01643	0.00477	-0.19925	0.40758
GFP	-0.01982	0.00080	**0.06628**	0.06343	-0.03154	-0.03492	-0.02698	0.00039	0.00073	-0.00737	-0.01676	-0.11097
SL	-0.02746	0.00650	0.03009	**0.13971**	-0.08595	-0.10777	0.08825	-0.01109	-0.02682	-0.02940	-0.11828	0.24705
SS	-0.02318	0.00484	0.00992	0.05701	**-0.21062**	0.10742	0.08993	-0.01373	-0.02152	-0.02406	-0.09921	-0.00571
SD	0.00464	-0.00133	-0.01163	-0.07566	-0.11369	**0.19902**	-0.00985	0.00350	0.00615	0.00241	0.01793	-0.20422
SW	-0.01987	0.00322	-0.00635	0.04380	-0.06729	-0.00696	**0.28149**	-0.09366	-0.05882	-0.02715	0.19147	0.43800
TGW	-0.00810	0.00427	-0.00021	0.01274	-0.02379	-0.00573	0.21690	**-0.12156**	0.04806	-0.00260	0.31097	0.18547
GWS	-0.02307	0.00351	-0.00073	0.05616	-0.06793	-0.01835	0.24815	-0.08756	**-0.06672**	-0.03199	0.11945	0.36629
NGS	-0.02257	0.00111	0.00801	0.06736	-0.08311	-0.00787	0.12530	-0.00518	-0.03500	**-0.06099**	0.03773	0.26752
HI	0.00336	0.00347	-0.00136	-0.02022	0.02556	0.00436	0.06594	-0.04625	-0.00975	-0.00281	**0.81730**	-0.47455
BY	-0.01631	-0.00578	-0.00731	0.03431	0.00119	-0.04040	0.12257	-0.02241	-0.02429	-0.01622	-0.38559	**0.95087**

PH: Plant height (cm), Till: Tillers per meter, GFP: Grain filling period, SL: Spike length (cm), SS: Spikelets per spike, SD: Spike density, SW: Spike weight (g), TGW: Thousand grain weight (g), GWS: Grain weight per spike (g), NGS: Number of grains per spike, HI: Harvest index, BY: Biological Yield (g/m) and GY: Grain yield (g/m)

Table 4. Genotypic, phenotypic and environmental correlation coefficients among yield and its Spike-related components in Bread wheat

Traits		PH	Tillers	GFP	SL	SS	SD	SW	TGW	GWS	NGS	HI	BY
Tillers	**rg**	-0.2127											
	rp	-0.1625											
GFP	**rg**	**0.4091**	-0.0561										
	rp	**0.3834**	-0.0187										
SL	**rg**	**0.5668**	**-0.4558**	**0.4541**									
	rp	**0.3141**	-0.1978	**0.2151**									
SS	**rg**	**0.4785**	**-0.3394**	0.1498	**0.4081**								
	rp	**0.4348**	**-0.2964**	0.1304	**0.2465**								
SD	**rg**	-0.0958	0.0934	-0.1755	**-0.5415**	**0.5398**							
	rp	-0.0751	0.0253	-0.1123	**-0.6586**	**0.4813**							
SW	**rg**	**0.4100**	**-0.2263**	-0.0959	**0.3135**	**0.3195**	-0.0351						
	rp	**0.3324**	-0.2088	-0.0645	0.0857	**0.2747**	0.0280						
TGW	**rg**	0.1673	**-0.2998**	-0.0033	0.0912	0.1130	-0.0288	**0.7705**					
	rp	0.1306	-0.2050	-0.0237	0.0511	0.0707	-0.0370	**0.5629**					
GWS	**rg**	**0.4760**	**-0.2463**	-0.0111	**0.4020**	**0.3226**	-0.0922	**0.8816**	**0.7203**				
	rp	**0.3616**	**-0.2142**	-0.0050	0.1314	**0.2725**	-0.0176	**0.8823**	**0.5004**				
NGS	**rg**	**0.4657**	-0.0782	0.1209	**0.4822**	**0.3946**	-0.0396	**0.4451**	0.0426	**0.5245**			
	rp	**0.4449**	-0.0830	0.1149	**0.2761**	**0.3947**	-0.0139	**0.3801**	0.0314	**0.4329**			
HI	**rg**	-0.0695	**-0.2438**	-0.0205	-0.1447	-0.1214	0.0219	**0.2343**	**0.3805**	0.1461	0.0461		
	rp	-0.0562	-0.1672	-0.0317	-0.0411	-0.1158	-0.0282	0.1586	**0.2183**	0.0857	0.0403		
BY	**rg**	**0.3366**	**0.4052**	-0.1103	**0.2456**	-0.0057	-0.2030	**0.4355**	0.1844	**0.3641**	**0.2659**	**-0.4718**	
	rp	**0.2617**	**0.5241**	-0.0788	0.1408	-0.0078	-0.1468	**0.2569**	0.0992	**0.2393**	0.1910	**-0.2734**	
GY	**rg**	**0.2577**	**0.2210**	-0.1167	0.1048	-0.1289	-0.1827	**0.6779**	**0.5203**	**0.4972**	**0.2923**	**0.3650**	**0.6456**
	rp	0.1849	**0.3839**	-0.0880	0.0913	-0.0887	-0.1422	**0.3675**	**0.2508**	**0.2797**	0.1927	**0.4050**	**0.7544**

Bold: Significant at 5% level, Unbold: Non-Significant, PH: Plant height (cm), Till: Tillers per meter, GFP: Grain filling period, SL: Spike length (cm), SS: Spikelets per spike, SD: Spike density, SW: Spike weight (g), TGW: Thousand grain weight (g), GWS: Grain weight per spike (g), NGS: Number of grains per spike, HI: Harvest index, BY: Biological Yield (g/m) and GY: Grain yield (g/m).

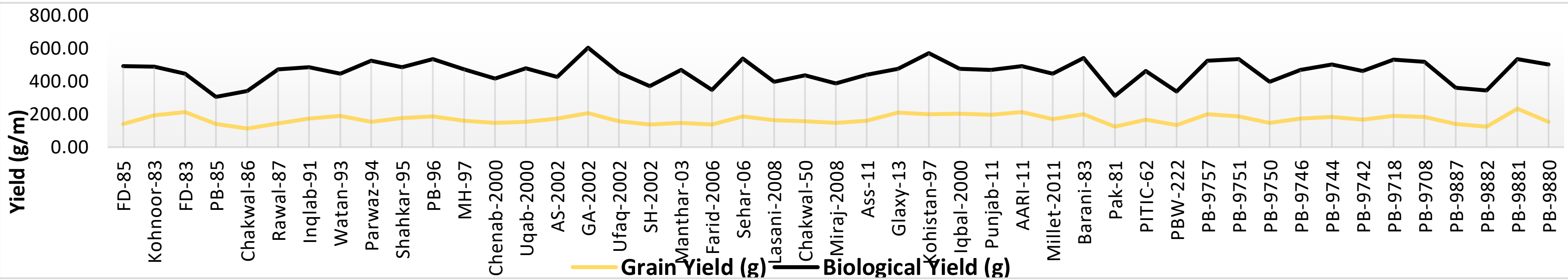

Figure 3. Grain and Biological yield comparison of different genotypes