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Correlation and path coefficient analysis of grain yield and Agronomic characters of bread wheat (*Triticum aestivum* L.) under rainfed conditions

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Abstract

The following study was done during the winter seasons of 2015-2016 at Qlyasan Agricultural Research Station, College of Agricultural Sciences, University of Sulaimani, using factorial (6×6×4) design conducted in Randomized Completely Block Design (RCBD) with three replicates to study the effect of planting date, plant densities and removal treatments of bread wheat (Adana-99) cultivars to establish the relationship between yield components and plant traits to the yield (output) of the grain. After the collection of data on bread wheat, a correlation analysis and a path analysis were carried out. Positive and highly significant correlation recorded between grain yield and the spike length, spike weight, number of spikelets/spike, number of grains/spike, weight of grains/spike, 1000- grain weight, harvest index and biological yield. Concerning the path coefficient analysis, grain yield represented the (dependent variable) and all characters, were the (independent) ones. Maximum and positive direct effect on grain yield recorded by biological yield was (0.855) and followed by harvest index was (0.337). While number of grains/spike was (-0.045) recorded maximum negative direct effect on grain yield. These relations can be used as selection criteria in breeding studies to improve the higher yields cultivars for that region.

Introduction:

Wheat (*Triticum aestivum* L.) is considered as one of the most crucial crop, widely cultivated throughout the world, with the main purpose of human consumption, supporting approximately 35% of the world's population and 95% of wheat grown today is bread wheat *[1]*. The grain yield of wheat (*Triticum aestivum* L.) is affected by several morphological and physiological processes which take place as the wheat is growing. These processes take place in different growing stages of the wheat. It is important to note that other yield components have a greater impact on grain field than others at different stages of the plant's growth *[2]*. In agronomic and breeding studies, correlation coefficients are generally used to determine the relation of grain yield and yield components. Simple correlation coefficients detected that 1000 grain weight and number of grains/spike showed significant positive correlations with grain yield *[3]*, grain yield had positive correlation with spike length, grains/spike and 1000-grain weight *[4]*. The correlation coefficient is an important statical method which can help wheat breeders in selection for higher yields. Some of the researchers indicated the positive correlation between grain yield and yield component traits in wheat such as spike number/plant *[5]*, grains number/spike *[6]*, 1000 grain weight *[7]* and biological yield *[8]*. Estimation of the correlation between yield and its components alone is not sufficient to understand the importance of each one of these components in determining the grain yield reported by *[8, 9* and *10]*.

Unlike the correlation coefficient, which measures the extent of the relationship, the path coefficient measures the magnitude of direct and indirect contribution of a component character to a complex character and it has been defined as a standardized regression coefficient which splits the correlation coefficient into direct and indirect effects *[11]*. Path coefficients have been used to develop selection criteria for complex

traits in several crop species of economic importance such as wheat *[12* and *13]*. Path analysis grains/spike followed by 1000-grain weight, spikes/plant and harvest index had positive direct effects on grain yield of bread wheat obtained from *[14]*. The path coefficient analysis provides more information among variables than do correlation coefficients since this analysis provides the direct effects of specific yield components on yield and indirect effects via other yield components *[15* and *16]*. In agriculture, path analyses have been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield *[17* and *18]*. A study of path analysis *[4]*, indicated that 1000-grain weight had the highest positive direct effect on yield followed by spike length and days to heading while, plant height, grains/spike and peduncle length had a negative direct effect on yield.

The main objectives of the current research study were: (i) to evaluate associations between spike length (cm), spike weight (g), number of spikelets/ spike, number of grains/ spike, weight of grains /spike (g), 1000 grain weight (g), harvest index (H.I.), and biological yield (ton/ha) with grain yield (ton/ha), (ii) to determine direct and indirect effects of yield components and plant traits on grain yield in bread wheat grown under different growing conditions.

Material and Methods:

The current research was performed at the Agricultural Research Station at Qlyasan, College of Agricultural Sciences, Sulaimani University. The research was carried out in the 2015-2016 season. In order to study the response of bread wheat (Adana-99) under six planting dates (15th Nov. 2015 to 25th Feb. 2016) with 20 days interval, six plant densities (120, 140, 160,180, 200 and 220) kg/ha and four removal treatments which were control; (awns removal, flag leaf removal and both (awns+flag leaf) removal) on yield and yield components. The experimental design was conducted according to the (6×6×4) factorial CRBD with three replications. Each plot consists of five rows of 2.0 m length with row spacing in each plot for wheat sowing was 0.2 m, interspacing between two replications was 1 m and the plot size was 2 m^2.

The correlation coefficients were calculated to determine the degree of association of the yield and the other characters with also among the yield components themselves in phenotypic correlations were computed by using the formula given *[19*; *20]*. The path coefficient techniques include partitioning of the correlation coefficient to determine direct (unidirectional path way `P') and indirect effects through alternative path ways (Path way `P' X correlation coefficient `r') of various variables and grain yield per plant. Grain yield was considered as the resultant variable and the others as causal variables. The path coefficient analysis was carried according to the equations as suggested by Arbuckle, 2009, Deway and Lu, 1959, Singh and Chaudhary, 1985 and Soomra, 2010 *[11; 17; 20*; *21]* through (Analysis of Moment Structures) AMOS Ver. 18 Software.

In research, direct and indirect impacts of traits were evaluated by correlation and path coefficients.

Studied Characteristics

The spike length (cm), the spike weight (g), the number of spikelets/spike, the number of grains/spike, weight of grains/spike (g), 1000 grain weight (g), the harvest index (H.I.), the biological yield (ton/ha), and the grain yield (ton/ha).

Correlation Analysis and Path Coefficient Analysis

Calculation of correlation coefficients was done to establish the relationship between the yield and grain traits. The path coefficient technique which subdivides the correlation coefficient to determine the direct and indirect impacts of grain traits on grain yields were used as well.

Result and Discussion

Table (1) explained means of triple combination between the studied factors; Planting dates, plant density, and removal treatments and their effects on grain yield and its components Maximum number of spike length, number of spikelets/spike, number of grains/spike, weight of grains/spike and 1000 grain weight was 8.917 cm, 17.083, 40.098, 1.862 g and 38.916 g, respectively produced by the combination between (15th

Nov. 2015 under the planting density of 120 kg/ha and the treatment of control). Maximum value of spike weight was 2.160 g exhibited by the combination between (15th Nov. 2015 under the planting densities of 140 kg/ha, and the treatment of control).Maximum value of harvest index was 0.497 produced by the combination between (15th Jan. 2016 under the planting density of 220 kg/ha and the treatment of control). While maximum values of biological yield and grain yield was 14.803 tons/ha and 5.844 ton/ ha, respectively produced by the combination between (15th Nov. 2015 under the planting density of 200 kg/ha and the treatment of control). The optimal planting date and plant densities of winter wheat breeds, due to the climate-change of habitats, not only from Agra-technical factors (sowing date), but also from the economic point of view *[22]*. The proper sowing date brings the highest yield in wheat grain *[23]*.

Like planting dates, balance plant density have also a significant role in the crop production system of wheat. Wheat variety reacts in different ways to various levels of plant densities. Plant density affects the plant population, number of tillers/m^2, 1000 grain weight and straw yield *[24]*. As a result, the flag leaf, the awned and the second upper leaf blade are the most important photosynthesis part of the plant and nearly half of the dry material which is accumulated by the grain is obtained by these organs *[25]*.

Table- 1: Mean values for some morphological traits in bread wheat.

Planting Dates	Plant Density (Kg/ha)	Removal Treatments	Spike length (cm)	Spike weight (g)	No. of spikelets/ spike	No. of grains/ Spike	Weight of grains/ spike (g)	1000 grain weight (g)	Harvest index	Biological yield (Tons/ha)	Grain yield (tons/ha)
15th Nov. 2015	120	Control	8.917	1.788	17.083	40.098	1.862	38.916	0.408	10.733	4.378
		Awn	8.093	1.955	16.433	34.867	1.638	37.704	0.405	10.460	4.242
		Flag leaf	8.039	1.763	15.993	35.474	1.586	34.484	0.433	9.339	4.033
		Both	7.257	1.639	15.167	32.733	1.335	33.294	0.431	8.687	3.746
	140	Control	8.897	2.160	15.833	39.167	1.824	38.136	0.469	9.651	4.528
		Awn	8.124	1.960	14.773	34.506	1.691	36.263	0.453	9.570	4.331
		Flag leaf	7.370	1.824	15.033	35.533	1.462	33.940	0.474	8.607	4.082
		Both	7.233	1.703	14.183	31.941	1.280	31.042	0.483	7.852	3.794
	160	Control	8.767	1.698	15.467	37.633	1.567	37.156	0.374	13.865	5.184
		Awn	7.463	1.600	14.820	33.783	1.487	35.344	0.406	12.344	5.001
		Flag leaf	7.853	1.434	14.580	34.650	1.244	33.153	0.383	12.416	4.753
		Both	7.293	1.342	14.087	31.387	1.142	30.073	0.401	11.082	4.443
	180	Control	8.283	1.614	13.833	36.040	1.334	36.122	0.387	14.403	5.566
		Awn	8.430	1.438	12.967	32.633	1.263	34.222	0.389	13.571	5.276
		Flag leaf	6.570	1.305	12.067	33.400	1.032	32.025	0.370	13.364	4.936
		Both	7.223	1.161	11.633	30.000	0.931	29.638	0.389	11.746	4.567
	200	Control	8.057	1.661	14.267	34.033	1.305	36.135	0.395	14.803	5.844
		Awn	8.010	1.526	13.900	30.633	1.208	33.961	0.404	13.617	5.492
		Flag leaf	7.763	1.437	13.333	31.467	1.042	31.750	0.389	13.268	5.158
		Both	8.067	1.332	12.800	28.200	0.931	29.885	0.422	12.272	5.169
	220	Control	7.603	1.426	14.073	31.509	1.091	33.219	0.403	13.318	5.363
		Awn	8.280	1.338	13.687	28.833	1.007	32.157	0.416	12.619	5.248
		Flag leaf	7.727	1.241	13.067	29.133	0.914	29.969	0.417	11.692	4.869
		Both	6.927	1.136	12.460	24.700	0.937	28.222	0.429	10.699	4.586
5th Dec. 2015	120	Control	8.380	1.924	16.000	38.167	1.752	31.969	0.419	9.707	4.056
		Awn	7.560	1.750	15.190	34.618	1.657	29.325	0.414	8.955	3.702
		Flag leaf	8.210	1.550	14.853	35.656	1.453	27.590	0.460	7.582	3.484
		Both	7.670	1.349	14.453	33.181	1.255	26.338	0.483	6.889	3.326
	140	Control	7.527	1.856	15.477	33.452	1.646	30.651	0.463	9.502	4.400
		Awn	7.010	1.765	14.847	30.511	1.532	29.771	0.483	9.003	4.344
		Flag leaf	6.943	1.346	14.867	30.933	1.350	27.600	0.472	8.822	4.167
		Both	6.625	1.130	14.170	27.417	1.167	26.703	0.468	8.712	4.080
	160	Control	7.593	1.623	14.733	32.233	1.454	32.074	0.488	10.242	5.000
		Awn	7.063	1.436	13.930	29.766	1.356	30.961	0.494	10.017	4.949
		Flag leaf	7.263	1.174	13.500	29.333	1.115	30.151	0.491	9.788	4.805
		Both	7.103	0.930	12.867	26.314	1.031	28.486	0.483	9.620	4.648
	180	Control	7.719	1.416	14.273	32.117	1.268	30.116	0.487	11.327	5.515
		Awn	7.403	1.344	13.367	29.033	1.156	29.226	0.462	10.992	5.079

25th Dec. 2015	200	Flag leaf	7.283	1.271	12.657	29.233	1.037	27.333	0.478	9.799	4.678
		Both	6.753	1.139	12.350	26.033	0.934	26.252	0.481	8.950	4.306
		Control	7.147	1.294	13.433	30.300	1.170	30.901	0.451	13.160	5.932
		Awn	6.933	1.261	13.233	26.900	1.040	29.412	0.450	12.867	5.791
		Flag leaf	6.357	1.153	12.500	27.733	0.949	27.603	0.398	12.694	5.048
		Both	5.993	1.053	11.883	23.500	0.874	26.676	0.411	12.516	5.138
	220	Control	7.513	1.311	13.633	29.067	1.135	30.480	0.415	13.352	5.536
		Awn	7.043	1.198	12.867	27.000	1.041	29.155	0.410	13.121	5.373
		Flag leaf	6.735	1.054	12.533	27.200	0.920	27.990	0.410	12.413	5.084
		Both	6.474	1.028	12.257	25.217	0.852	27.434	0.404	12.347	4.983
	120	Control	7.572	1.714	14.803	34.815	1.550	35.945	0.386	11.267	4.341
		Awn	7.270	1.552	13.800	30.689	1.437	33.083	0.367	10.883	3.995
		Flag leaf	6.450	1.355	12.433	31.653	1.245	31.704	0.385	9.955	3.829
		Both	6.273	1.262	11.877	28.857	1.154	31.390	0.395	9.548	3.770
	140	Control	7.404	1.550	14.226	34.285	1.329	34.674	0.472	9.874	4.661
		Awn	6.593	1.451	12.984	30.906	1.148	31.780	0.467	9.573	4.473
		Flag leaf	5.980	1.273	12.333	32.015	1.025	29.797	0.487	8.226	4.006
		Both	5.630	1.161	11.817	27.800	0.953	28.483	0.481	7.963	3.829
	160	Control	6.578	1.451	13.273	32.333	1.217	33.393	0.446	10.853	4.843
		Awn	6.371	1.349	12.537	28.607	1.132	31.196	0.467	9.830	4.597
		Flag leaf	6.261	1.271	11.600	29.559	1.030	30.097	0.478	9.267	4.429
		Both	5.775	1.147	10.710	26.815	1.024	28.927	0.445	9.263	4.126
	180	Control	6.840	1.332	12.657	29.675	1.127	33.557	0.495	10.605	5.243
		Awn	6.438	1.228	10.807	26.319	1.015	32.681	0.494	10.337	5.106
		Flag leaf	5.953	1.016	10.100	26.233	0.964	30.828	0.494	9.728	4.804
		Both	5.772	0.966	9.620	23.130	0.847	29.637	0.494	9.379	4.631
	200	Control	6.826	1.245	12.093	28.207	1.049	32.832	0.493	11.236	5.532
		Awn	6.217	1.109	11.533	24.900	0.921	31.837	0.487	11.024	5.365
		Flag leaf	5.698	0.923	11.420	25.633	0.843	32.088	0.494	10.868	5.365
		Both	5.340	0.885	10.067	22.287	0.721	29.119	0.489	10.333	5.057
	220	Control	6.524	1.232	12.130	26.626	1.022	31.625	0.431	12.742	5.491
		Awn	5.827	1.154	11.367	23.233	0.948	30.593	0.431	12.399	5.340
		Flag leaf	5.897	1.043	11.117	23.322	0.843	29.379	0.431	12.122	5.220
		Both	5.680	1.210	10.600	20.533	0.750	28.672	0.431	11.779	5.073
	120	Control	7.201	1.547	13.203	27.653	1.356	31.878	0.340	9.893	3.369
		Awn	6.133	1.462	11.840	24.527	1.347	29.927	0.373	8.482	3.161
		Flag leaf	5.720	1.237	11.233	23.967	1.040	28.689	0.403	7.523	3.030
		Both	5.560	1.142	10.100	20.767	0.950	27.244	0.434	6.651	2.878
	140	Control	6.795	1.362	12.607	25.558	1.164	31.746	0.379	9.919	3.754
		Awn	5.712	1.255	10.757	21.903	1.058	28.892	0.354	9.653	3.417
		Flag leaf	5.263	1.032	9.800	22.900	0.932	27.908	0.359	9.199	3.300
		Both	4.873	0.926	9.133	19.300	0.853	27.283	0.403	8.063	3.248
	160	Control	6.303	1.168	11.567	23.333	0.958	31.086	0.441	9.263	4.078
		Awn	5.636	1.071	10.607	20.274	0.866	27.719	0.450	8.237	3.708
		Flag leaf	5.571	0.985	10.250	21.342	0.714	27.021	0.452	8.000	3.616
		Both	5.862	0.856	9.619	17.543	0.645	26.315	0.479	7.367	3.519
	180	Control	7.552	1.037	11.423	22.547	0.867	30.379	0.484	9.133	4.418
		Awn	7.051	0.950	11.357	20.430	0.730	28.714	0.488	8.559	4.177
		Flag leaf	6.845	0.813	11.000	20.283	0.670	27.135	0.449	8.516	3.817
		Both	6.389	0.740	11.497	17.348	0.609	24.703	0.484	7.151	3.462
	200	Control	6.338	0.939	11.523	20.778	0.755	30.195	0.446	10.197	4.544
		Awn	6.267	0.886	11.383	19.033	0.685	28.451	0.441	9.783	4.315
		Flag leaf	5.447	0.777	10.333	17.900	0.622	27.407	0.453	9.300	4.212
		Both	5.207	0.544	10.067	15.467	0.529	25.906	0.464	9.003	4.175
15th Jan. 2016	220	Control	6.715	0.851	11.603	21.304	0.842	30.537	0.497	10.522	5.235
		Awn	5.970	0.819	11.333	19.450	0.763	29.347	0.472	10.061	4.752
		Flag leaf	6.159	0.744	11.223	20.052	0.627	27.992	0.486	9.661	4.695
		Both	5.673	0.627	10.667	17.667	0.559	26.011	0.489	8.878	4.341

To be continued

Table- 1: Mean values for some morphological traits in bread wheat.

Planting Dates	Plant Density (Kg/ha)	Removal Treatments	Spike length (cm)	Spike weight (g)	No. of spikelets/ spike	No. of grains/ spike	Weight of grains/ spike (g)	1000 grain weight (g)	Harvest index	Biological yield (Tons/ha)	Grain yield (tons/ha)
5th Feb. 2016	120	Control	6.069	1.312	10.777	24.664	1.157	29.773	0.416	5.934	2.466
		Awn	5.657	1.160	10.300	22.633	1.042	28.873	0.416	5.755	2.392
		Flag leaf	5.653	1.051	10.050	22.643	0.942	27.400	0.413	5.493	2.268
		Both	5.275	1.013	9.717	20.517	0.828	25.930	0.416	5.325	2.214
	140	Control	6.457	1.244	11.533	24.200	1.046	29.719	0.417	6.736	2.813
		Awn	5.933	1.114	10.933	22.400	0.935	28.422	0.419	6.441	2.697
		Flag leaf	5.533	1.029	10.667	22.133	0.864	27.265	0.417	6.187	2.582
		Both	5.220	0.948	10.267	19.667	0.759	26.499	0.417	6.007	2.507
	160	Control	5.860	1.100	11.117	23.683	0.922	28.809	0.409	7.078	2.891
		Awn	5.360	1.045	10.853	21.810	0.847	27.444	0.409	6.811	2.782
		Flag leaf	5.107	0.957	11.100	22.410	0.717	26.303	0.408	6.602	2.697
		Both	5.077	0.830	9.933	19.856	0.634	25.135	0.409	6.311	2.579
	180	Control	5.757	1.069	10.300	23.675	0.936	29.823	0.435	7.917	3.444
		Awn	5.253	0.923	10.233	20.600	0.863	27.716	0.435	7.079	3.078
		Flag leaf	4.933	0.833	9.967	20.333	0.753	26.620	0.440	7.037	3.093
		Both	4.420	0.700	9.733	15.933	0.736	24.764	0.435	6.461	2.810
	200	Control	6.060	0.983	10.133	21.067	0.947	27.994	0.433	8.082	3.501
		Awn	5.463	0.966	9.317	19.100	0.842	25.992	0.432	7.513	3.249
		Flag leaf	5.407	0.829	9.567	19.383	0.761	24.900	0.432	7.198	3.113
		Both	5.120	0.700	9.300	15.667	0.679	23.997	0.432	6.920	2.992
	220	Control	4.327	0.956	9.053	21.510	0.793	27.539	0.455	8.210	3.734
		Awn	3.807	0.891	8.533	19.400	0.741	24.251	0.455	7.229	3.288
		Flag leaf	4.396	0.744	8.830	18.630	0.641	22.350	0.455	6.665	3.031
		Both	4.167	0.713	8.667	15.444	0.574	21.049	0.455	6.280	2.855
25th Feb. 2016	120	Control	5.600	1.235	10.533	22.077	1.039	28.311	0.324	4.771	1.546
		Awn	5.200	1.148	9.830	19.300	0.940	27.290	0.347	4.609	1.599
		Flag leaf	4.938	0.991	9.367	19.257	0.838	24.381	0.333	4.167	1.387
		Both	4.667	0.901	9.233	14.417	0.779	21.964	0.331	3.603	1.193
	140	Control	5.153	1.120	10.720	22.010	0.956	29.069	0.337	5.207	1.756
		Awn	4.680	0.911	10.467	19.333	0.841	28.234	0.341	4.997	1.706
		Flag leaf	4.470	0.763	10.267	19.333	0.743	23.557	0.353	4.041	1.422
		Both	3.883	0.684	9.670	15.833	0.648	21.020	0.337	3.766	1.269
	160	Control	5.380	1.049	10.900	21.667	0.915	27.022	0.347	5.669	1.967
		Awn	5.113	0.929	10.833	18.600	0.847	25.845	0.343	5.499	1.883
		Flag leaf	4.885	0.824	11.133	18.867	0.762	24.650	0.339	5.294	1.796
		Both	4.500	0.752	10.367	15.667	0.659	23.155	0.347	4.856	1.687
	180	Control	4.709	0.925	10.633	20.700	0.811	27.028	0.341	6.511	2.222
		Awn	4.410	0.844	10.500	17.767	0.755	26.218	0.343	6.117	2.099
		Flag leaf	4.220	0.619	10.567	17.933	0.653	24.731	0.347	5.643	1.958
		Both	4.075	0.549	10.240	15.200	0.491	22.549	0.414	5.178	2.142
	200	Control	4.850	0.842	10.117	20.267	0.731	26.481	0.342	7.411	2.532
		Awn	4.777	0.730	9.633	18.267	0.671	24.478	0.368	6.268	2.304
		Flag leaf	4.547	0.628	9.717	17.967	0.540	22.859	0.373	5.919	2.206
		Both	3.853	0.516	9.500	14.667	0.492	21.520	0.354	5.815	2.058
	220	Control	4.393	0.833	9.500	16.993	0.629	24.525	0.369	7.069	2.610
		Awn	4.037	0.751	9.033	15.143	0.547	22.850	0.369	6.742	2.488
		Flag leaf	3.893	0.661	8.867	15.080	0.465	21.709	0.366	6.398	2.344
		Both	3.903	0.520	8.867	12.133	0.392	20.131	0.359	6.051	2.171
Grand mean			6.211	1.155	11.825	25.020	0.992	28.923	0.423	8.940	3.318

Correlation among characters

The results of the correlation coefficient analysis between the grain yield and the yield traits show in Table (2). From the results, spike length recorded positively and high significantly correlative with spike weight (r= 0.829**), number of spikelets/spike (r= 0.896**), number of grains/spike (r= 0.883**), weight of

grains/spike (r= 0.804**), 1000 grain weight (r= 0.823**), harvest index (r= 0.325**), biological yield (r= 0.718**), and grain yield (r= 0.712**). Spikes weight gave positive and highly significant correlation with number of spikelets/ spike (r= 0.870**), number of grains/spike (r= 0.919**), weight of grains/spike (r= 0.961**), 1000 grain weight (r= 0.836**), biological yield (r= 0.508**) and grain yield (r= 0.471**). Number of spikelets/spike were recorded positive and highly significant correlation with the number of grains/ spike (r= 0.911**), weight of grains/spike (r= 0.881**), 1000 grain weight (r= 0.767**), harvest index (r= 0.222**), biological yield (r= 0.595**) and grain yield (r= 0.577**). Number of grains/spike exhibited positive and highly significant correlated with weight of grains/spike (r= 0.909**), 1000 grain weight (r= 0.847**), harvest index (r= 0.246**), biological yield (r= 0.642**) and grain yield (r= 0.619**). Weight of grains/spike was recorded positive and highly significant correlation with 1000 grain weight (r= 0.805**), biological yield (r= 0.443**) and grain yield (r= 0.415**). 1000 grain weight was recorded positive and highly significant correlated with harvest index (H.I.) (r= 0.243**), biological yield (r= 0.691**) and grain yield (r= 0.664**). While harvest index exhibited positive and highly significant correlated with biological yield (r= 0.286**) and grain yield (r= 0.577**) and biological yield correlated positive and highly significant with grain yield (r= 0.944**).

The results consent with the positive and highly significant correlation between grain weight/spike and 1000 grain weight obtained by *[26 ; 27]*. Positive and significant relationships existed between grain yield and biological yield and number of spike/plant, respectively *[28]*. Some authors also reported positive and significant correlations between yield and grain number *[5 ; 29]* and above ground biomass *[30]*. Some researchers reported a positive association between total number of grain/spike and 1000 grain weight *[31 ; 32]*. Grain yield had positive correlation with spike length, number of spikelets/spike, number of grain/spike, 1000 grain weight and harvest index at both phenotypic and genotypic level *[33]*. Positive and significant correlation between spike length, number of pikelet/spike, number of grains/spike, 1000 grain weight, biological yield and harvest index with grain yield there is a possibility to increase grain yield of bread wheat *[34 ; 35]*.

Table -2: Correlation coefficient analysis, among the studied characters.

Characters	*Spike length (cm)*	*Spike weight (g)*	*No. of spikelets/ spike*	*No. of grains/ spike*	*Weight of grains/ spike (g)*	*1000 grain weight (g)*	*Harvest index*	*Biological yield (Tons/ha)*
Spike weight (g)	*0.829***							
No. of spikelets/spike	*0.896***	*0.870***						
No. of grains/spike	*0.883***	*0.919***	*0.911***					
Weight of grains/spike (g)	*0.804***	*0.961***	*0.881***	*0.909***				
1000 grain weight (g)	*0.823***	*0.836***	*0.767***	*0.847***	*0.805***			
Harvest index	*0.325***	*$0.142^{n.s}$*	*0.222***	*0.246***	*$0.133^{n.s}$*	*0.234***		
Biological yield (Tons/ha)	*0.718***	*0.508***	*0.595***	*0.642***	*0.443***	*0.691***	*0.286***	
Grain yield (tons/ha)	*0.712***	*0.471***	*0.577***	*0.619***	*0.415***	*0.664***	*0.577***	*0.944***

**. Correlation is significant at the 0.05 level (2-tailed) , $t_{0.05}$ (142)=1.977*

***. Correlation is significant at the 0.01 level (2-tailed) , $t_{0.01}$ (142)=2.611*

Path coefficient analysis

All the direct and indirect traits can be seen in Table (3). In the current study, the grain yield (ton/ha) (which is the response variable) together with spike length (cm), spike weight (g), number of spikelets/ spike, number of grains/ spike, weight of grains /spike (g), 1000 grain weight (g), harvest index and biological yield (ton/ha) (which are the determinative variables) are applied in the path coefficient analysis.

From the results in Table (3), it can be observed that the biological yield had the highest positive direct impact on the grain yield with (0.855), researches that have reported similar findings include ***[36]***, and followed by harvest index which was (0.337). Number of grains/spike with (-0.045) recorded maximum

negative direct effect on grain yield. The character spike length recorded maximum positive indirect effect on grain yield via biological yield (0.614), followed by 1000 grain weight via biological yield (0.591), while the maximum negative indirect effect recorded by spike weight via a number of grains/spike reaching (-0.041), number of spikelets/spike via a number of grains/spike reaching (-0.041), and weight of grains/spike via a number of grains/spike reaching (-0.041).

The path coefficient analysis showed that harvest index and biological yield had the maximum positive direct effect on grain yield of wheat *[8]*. The highest positive direct effect on grain yield were exhibited by biological yield, which had positive and significant correlation with grain yield *[33]*. In most of previous studies, biological yield and harvest index had a positive direct effect on the grain yield *[37; 38]*.

Table- 3: Path coefficient analysis of direct and indirect effect of different traits on grain yield.

Characters	*Spike length (cm)*	*Spike weight (g)*	*No. of spikelets/spike*	*No. of grains/spike*	*Weight of grains/spike (g)*	*1000 grain weight (g)*	*Harvest index*	*Biological yield (Tons/ha)*
Spike length (cm)	***-0.036***	*-0.030*	*-0.032*	*-0.032*	*-0.029*	*-0.030*	*-0.012*	*-0.026*
Spike weight (g)	*-0.015*	***-0.018***	*-0.016*	*-0.016*	*-0.017*	*-0.015*	*-0.003*	*-0.009*
No. of spikelets/spike	*0.050*	*0.049*	***0.056***	*0.051*	*0.050*	*0.043*	*0.013*	*0.034*
No. of grains/spike	*-0.040*	*-0.041*	*-0.041*	***-0.045***	*-0.041*	*-0.038*	*-0.011*	*-0.029*
Weight of grains/spike (g)	*0.003*	*0.004*	*0.003*	*0.004*	***0.004***	*0.003*	*0.001*	*0.002*
1000 grain weight (g)	*0.025*	*0.025*	*0.023*	*0.026*	*0.024*	***0.030***	*0.007*	*0.021*
Harvest index	*0.109*	*0.048*	*0.075*	*0.083*	*0.045*	*0.079*	***0.337***	*0.096*
Biological yield (Tons/ha)	*0.614*	*0.434*	*0.509*	*0.549*	*0.379*	*0.591*	*0.245*	***0.855***
Grain yield Correlation	***0.712****	***0.471****	***0.577****	***0.619****	***0.415****	***0.664****	***0.577****	***0.944****

Conclusion

Correlation analysis obtained from bread wheat (Adana-99) showed that the association of grain yield/plant was positive and highly significant correlated with spike length, spike weight, number of spikelets/spike, number of grains/spike, weight of grains/spike, 1000 grain weight, the harvest index and biological yield. Path coefficient analysis indicated that the direct effect of spike length, spike weight and number of grains/spike in grain yield were weakly negative. The direct effect of number of spikelets/spike, weight of grains/spike, 1000 grain weight, harvest index and biological yield was strongly positive, while the spike length, spike weight and number of grains/spike had a strongly negative effect. Therefore, the character of spike length and number of grains/spike can be used as selection criteria to increase grain yield in bread wheat in the region.

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