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Genotypic and phenotypic associations, direct and indirect effects of yield contributing traits on yield in wheat (*Triticum aestivum* L.) under sodic soil condition

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Abstract
The experiment was conducted to work out the correlation and path coefficient effects of their various attributes on grain yield in wheat with 108 genotypes along with 4 check varieties *viz.*, KH-65, KRL-1702, KRL-1714, NW-1014. The experiment was conducted under sodic soil (pH = 9.5) in randomized block design with three replications. The yield and yield contributing traits were utilized for estimation of correlation coefficients. In general, genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients suggesting that strong genetic correlation among the yield and yield contributing components of wheat. Grain yield per plant exhibited a highly significant and positive correlation with harvest index (0.477) followed by biological yield per plant (0.232), tiller per plant (0.153), days to 50% flowering (0.152), spike length (0.145) and days to maturity (0.132) in sodic soil.The highest positive direct effect on grain yield per plant was exerted by harvest index (1.439) followed by the biological yield per plant (1.295), spike length (0.013) and days to maturity (0.007). Therefore, these characters emerged as most important inter relationships of grain yield in wheat.

Keywords: Genetic correlation, phenotypic correlation and path coefficient

Introduction
Wheat is the world's most important crop that excels all other cereal crops both in area and production, thereby providing about 20.0 per cent of total food calories for the people of the world. Wheat (*Triticum aestivum* L. em. Thell.; 2n=42) is a self-pollinated crop of the member of *Poaceae* family and one of the most leading cereal of many countries of the world including India. It is the most important food crop of India and is a main source of protein and energy.In India, wheat is the second most important food crop after rice both in terms of area and production. It has been described as the 'King of cereals' because of the acreage it occupies, high productivity and the prominent position it holds in the international food grain trade. It is a C_3 plant grown in temperate, irrigated to dry and high-rain-fall areas and in warm, humid to dry, cold environments. Wheat is consumed in a variety of ways such as *bread, chapatti, porridge, flour, suji* etc. Wheat has relatively high content of niacin and thiamin which are principally concerned in providing the special protein called '*Glutin'*. Wheat proteins are of special significance because *Glutin* provides the framework of spongy cellular texture of bread and baked products The majority of the cultivated wheat varieties belong to three main species of the genus *Triticum*. The extent of genetic variability has been considered as an important factor which is an essential pre-requisite for a successful hybridization aimed at producing high yielding progenies. The selection of parents becomes more difficult if the improvement is made for a poly genetically controlled complex character like grain yield. Since, efficient selection of genetically superior individuals requires adequate phenotypic variance in the base population and sufficient high heritability. Correlation studies along with path analysis provide a better understanding of the association of different characters with grain yield. Correlation is useful in disclosing the magnitude and direction of relationship between various yield contributing traits and yield. While path coefficient (or) standardized partial regression coefficient that measures the direct effect of a predictor variable upon its response variable and the second component being the indirect effect(s) of a predictor variable (Dewey and Lu, 1959).

These are the hexaploid (2n=42), *T. aestivum* L. (bread wheat), the tetraploid (2n=28), *T. durum* Desf, the diploid (2n=14), *T. dicoccum* Schrank and *T. monococcum.* Globally, *aestivum* wheat is most important species which covers 90 per cent of the area next popular wheat being *durum* which covers about 9 per cent of the total area while *T. diccoum* and *T. monococcum* cover less than the one per cent of the total area. This wheat is cultivated predominantly in sub-tropical countries, amongst these, Egypt has the highest productivity of 5 tones per hectare for spring wheat which is obtained due to large consumption of fertilizers. Same holds true for the winter wheat growing areas where, productivity is even higher due to the higher production potential of such types which is attributed to much longer growing period. Punjab state on the whole has achieved a productivity level of 4.8 tonnes / ha on 3.5 million hectares.

The perusal of state wise production of wheat indicated that Uttar Pradesh top the list with 32.09 mt, followed by Madhya Pradesh (18.58 mt), Punjab (18.21 mt), Haryana (12.07 mt), Rajasthan (10.57 mt) and Bihar (6.55mt), These top six states together contributed about 93 per cent of the total production (Anonymous 2019-20).

Materials and Method

The study was designed to work out the status of association for different grain yield traitson grain yield per plant among 108genotypes of wheat including along with 4 checks varieties *viz.*, KH-65, KRL-1702, KRL-1714, NW-1014 Field experiment was conducted during *Rabi*, 2019-20 at the Main Experimental Station of A.N.D. University of Agriculture & Technology, Narendra Nagar (Kumarganj), Ayodhya, U.P. India in sodic soil Randomized Block Design with three replications in sodic soil. The observation were recorded on twelve different grain yield traits *viz.*, days to 50% flowering, days to maturity, plant height (cm), tillers per plant, flag leaf area (cm), spike length (cm), panicle length (cm), number of grains per panicle, grain yield per plant(g), test weight (g), biological yield per plant (g), harvest index. Correlation coefficients were estimated as suggested by Searle, 1961 and path-coefficient analysis by Dewey and Lu, 1959 [1].

Results and Discussion

Estimation of correlation co-efficient among the traits

Calculation of correlation between yield and its traits and among the traits plays an important role in selection of desirable genotypes. Genotypic and phenotypic correlations were in perfect agreement with each other and relatively higher magnitude of genotypic correlations indicated the masking effect of the environment (Table1). The genotypic and phenotypic correlation coefficient was worked out to measure the association among the characters in sodic soil conditions. In sodic condition Grain yield per plant exhibited highly positive phenotypic correlation with harvest index (0.477) followed by biological yield per plant (0.232), tiller per plant (0.153), days to 50% flowering (0.152), spike length (0.145) and days to maturity (0.132) and negative correlation rest of the characters under study. The strong positive association of grain yield with the characters mentioned above has also being reported by earlier workers Singh, Bhuri and Upadhyay, P.K. (2013) [3], Ayccek and Yldrm (2006) [4], Sherif *et al.*(2005), Payal *et al.* (2007) [5], Dharmendra and Singh (2010) [6], Tripathi *et al*. (2011) [7], El-Mohsen *et al.* (2012) [8] and Bhutto *et al*. (2015) [9].

In sodic condition days to maturity showed high positive correlation and tillers per plant showed negative correlation for this character.The association of days to 50 per cent flowering with different morphological and physiological traits has also been reported by Sherif *et al.* (2005), Ayccek and Yldrm (2006) [4], Prasad *et al.* (2006), Payal *et al.* (2007) [5], Yousaf *et al.* (2008), Nagireddy and Jyothula (2009), Dharmendra and Singh (2010) [6], Raiz-ud-Din *et al.* (2010), El-Mohsen *et al.* (2012) [8] andBhutto *et al*., (2015) [9].

In sodic condition tillers per plant (0.176) followed by spike length (0.118) and number of seed per spike (0.121), and rest of the characters either very less or non significant.

Tillers per plant showed only positive correlation with biological yield (0.124) and negative correlation with test weight (-0.120) in sodic condition.

Flag leaf area showed non-significant correlation for all the characters under study in sodic condition. Spike length showed positive correlation with biological yield per plant (0.252) followed by number of seed per spike (0.175). Peduncle length showed positively correlated with harvest index (0.158). Whereas, it had non-significant correlation with all the traits.

Number of seed per spike had non-significant correlation with all the characters it showed positive correlation with biological yield per plant (0.127) and it exhibited negative association with harvest index (-0.123) followed by 1000-seeed weight (-0.121). 1000-seed weight (test weight) showed non-significant correlation with all characters. Biological yield per plant showed negative association with harvest index (-0.741) in sodic soil respectively. Correlation study of twelve traits revealed that besides grain yield traits are also correlated with each other. Thus, selection practiced for improving these traits individually or simultaneously would bring improvement in other due to correlated response. This suggested that selection would be quite efficient in improving yield and yield components in wheat

The direct and indirect effects of 12 characters on grain yield per plant estimated by path coefficient analysis using simple correlations are given in table 1.

Table 1: Estimates of phenotypic and genotypic correlation coefficient between 12 characters under sodic soil in wheat

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Tiller per plant	Flag leaf area (cm)	Spike length (cm)	Peduncle length (cm)	Numbers of Seed per spike	1000-seed weight (g)	Biological yield per plant	Harvest index (%)	Grainyield per plant (g)
Days to 50% flowering	P	1.000	0.560**	0.515**	0.131*	-0.046	0.115*	-0.031	0.024	-0.031	0.077	0.040	0.152**
	G	1.000	0.918**	0.687**	0.308**	-0.253**	0.229**	-0.109*	-0.003	-0.088	0.156**	0.012	0.203**
Days to maturity	P		1.000	0.425**	0.056	-0.066	0.092	0.004	-0.004	0.025	0.043	0.053	0.132*
	G		1.000	0.633**	0.265**	-0.319**	0.198**	-0.140*	-0.054	-0.027	-0.018	0.102	0.112*
Plant height (cm)	P			1.000	0.176**	0.087	0.118*	0.012	0.121*	0.008	0.043	0.039	0.104
	G			1.000	0.393**	0.226**	0.189**	0.019	0.316**	-0.022	0.032	0.088	0.142*
Tiller per plant	P				1.000	-0.074	0.049	-0.038	0.015	-0.120*	0.124*	-0.002	0.153**
	G				1.000	-0.079	0.170**	0.402**	0.184**	-0.240**	0.163**	0.086	0.307**

Flag leaf area (cm)	P					1.000	-0.017	0.036	-0.003	0.038	-0.086	0.043	-0.047
	G					1.000	-0.129*	0.506**	-0.088	-0.006	-0.333**	0.078	-0.295**
Spike length (cm)	P						1.000	-0.047	0.175**	-0.046	0.252**	-0.134*	0.145**
	G						1.000	-0.697**	0.390**	-0.073	0.389**	-0.187**	0.259**
Peduncle length (cm)	P							1.000	0.053	0.060	-0.093	0.055	-0.050
	G							1.000	-0.027	0.120*	-0.139*	-0.069	-0.244**
Numbers of Seed per spike	P								1.000	-0.121*	0.127*	-0.123*	-0.019
	G								1.000	-0.019	0.260**	-0.280**	-0.053
1000-seed weight (g)	P									1.000	-0.053	0.040	-0.024
	G									1.000	-0.064	0.015	-0.083
Biological yield per plant	P										1.000	-0.741**	0.232**
	G										1.000	-0.703**	0.320**
Harvest index(%)	P											1.000	0.477**
	G											1.000	0.445**

Table 2: Estimates of direct and indirect effect of 12 characters on grain yield per plant at phenotypic and genotypic level under sodic soil in wheat

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Tiller per plant	Flag leaf area (cm)	Spike length (cm)	Peduncle length (cm)	Numbers of Seed per spike	1000-seed weight (g)	Biological yield per plant(g)	Harvest index (%)	Grainyield per plant (g)
Days to 50% flowering	P	-0.0067	0.0042	-0.0040	-0.0005	-0.0002	0.0015	0.0002	-0.0002	0.0004	0.0994	0.0573	0.152**
	G	-0.0702	0.1849	-0.1020	-0.0002	-0.0347	-0.0051	0.0019	-0.0002	0.0016	0.2106	0.0160	0.203**
Days to maturity	P	-0.0037	0.0075	-0.0033	-0.0002	-0.0002	0.0012	0.0000	0.0000	-0.0004	0.0553	0.0758	0.132*
	G	-0.0645	0.2013	-0.0940	-0.0002	-0.0437	-0.0044	0.0024	-0.003	0.0005	-0.0238	0.1413	0.112*
Plant height (cm)	P	-0.0034	0.0032	-0.0077	-0.0007	0.0003	0.0016	-0.0001	-0.001	-0.0001	0.0559	0.0558	0.104
	G	-0.0482	0.1275	-0.1484	-0.0003	0.0309	-0.0042	-0.0003	0.0197	0.0004	0.0431	0.122	0.142*
Tiller per plant	P	-0.0009	0.0004	-0.0014	-0.0041	-0.0003	0.0006	0.0002	-0.0001	0.0017	0.1605	-0.0034	0.153**
	G	-0.0216	0.0533	-0.0583	-0.5308	-0.0108	-0.0037	-0.0069	0.0115	0.0045	0.2200	0.1201	0.307**
Flag leaf area (cm)	P	0.0003	-0.0005	-0.0007	0.0003	0.0037	-0.0002	-0.0002	0.0000	-0.0005	-0.111	0.0615	-0.047
	G	0.0178	-0.064	-0.0335	0.0001	0.1368	0.0029	-0.0086	-0.0045	0.0001	-0.4497	0.1090	-0.295**
Spike length (cm)	P	-0.0008	0.0007	-0.0009	-0.0002	-0.0001	0.0131	0.0131	-0.0015	0.0007	0.3260	-0.1929	0.145**
	G	-0.0161	0.0399	-0.0281	-0.0001	-0.0177	-0.0221	0.0119	0.0243	0.0014	0.5258	-0.2599	0.259**
Peduncle length (cm)	P	0.0002	0.0000	-0.0001	0.0002	0.0001	-0.0006	-0.0059	-0.0004	-0.0009	-0.1212	0.0788	-0.050
	G	0.0077	-0.028	-0.0029	-0.0003	0.0692	0.0154	-0.0017	-0.0017	-0.0023	-0.1872	-0.0964	-0.244**
Numbers of Seed per spike	P	-0.0002	0.0000	-0.0009	-0.0001	0.0000	0.0023	-0.0003	-0.0084	0.0017	0.164	-0.1767	-0.019
	G	0.0002	-0.0108	-0.0470	0.0001	-0.0120	-0.0086	0.0005	0.0622	0.0004	0.3503	-0.3883	-0.053
1000-seed weight (g)	P	0.0002	0.0002	-0.0001	0.0005	0.0001	0.0006	-0.0004	0.0010	-0.0143	-0.0684	0.0578	-0.024
	G	0.0062	0.0055	0.0032	0.0002	0.0009	0.0016	-0.0021	-0.0012	-0.0187	-0.0864	0.0205	-0.0830
Biological yield per plant	P	-0.0005	0.0003	-0.0003	-0.0005	-0.0003	0.0033	0.0006	-0.0011	0.0008	1.2959	-1.0666	0.232**
	G	-0.0110	-0.0036	-0.0047	-0.0001	-0.0456	-0.0086	0.0024	0.0161	0.0012	1.3500	-0.9759	0.320**
Harvest index (%)	P	-0.0003	0.0004	-0.0003	0.0000	0.0002	-0.0018	-0.0003	0.0010	-0.0006	-0.9605	1.4390	0.477**
	G	-0.0010	0.0205	-0.0130	-0.0001	0.0107	0.0041	0.0012	-0.0174	-0.0003	-0.9488	1.3886	0.445**

Estimation of path coefficient

The path coefficient analysis using genotypic as well as phenotypic correlation coefficient estimated In sodic condition were carried out to assess direct and indirect effects of twelve characters on the expression of grain yield per plant. The highest positive direct effect on grain yield per plant were exerted by harvest index (1.439), biological yield (1.295), spike length (0.013), days to maturity (0.007), and flag leaf area (0.003). While negative by tiller per plant (-0.004), peduncle length (-0.005) plant height (-0.007), days to 50% f lowering (-0.006).

The highest positive indirect effect on grain yield was exerted by spike length (0.326), via biological yield per plant followed by number of seed per spike (0.614) via biological yield per plant, tiller per plant (0.160) via biological yield per plant, days to 50% flowering (0.099) via biological yield per plant, days to maturity (0.055) via biological yield per plant, tiller per plant (0.001) and spike length (0.005) via biological yield per plant. Aside of this also have the negative indirect effect on grain yield was exerted by harvest index (-0.960) via biological yield per plant followed by peduncle length (-0.121), flag leaf area (-0.111) and test weight (-0.068) via biological yield per plant. At both genotypic and phenotypic level, Thus, the above mentioned characters emerged as most important direct yield contributors on which emphasis should be given during simultaneous selection aimed at improving grain yield in wheat. These characters have also been identified as major direct contributors towards seed yield by Singh, Bhuri and Upadhyay, P.K. (2013) [3], Ayccek and Yldrm (2006) [4], Sherif *et al.* (2005), Payal *et al.* (2007) [5],

Dharmendra and Singh (2010) [6], Tripathi *et al*. (2011) [7], El-Mohsen *et al.* (2012) [8] and Bhutto *et al*., (2015) [9]. The indirect effects of remaining characters were too low to be considered important. In the present study, path analysis identified biological yield per plant and harvest-index as most important direct as well as indirect yield contributing traits or components which merit due consideration at time of devising selection strategy aimed at developing high yielding varieties/hybrids in wheat.

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