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ASSESSMENT OF CORRELATION AND PATH COEFFICIENT FOR GRAIN YIELD, ITS ATTRIBUTES AND NITROGEN USE EFFICIENCY IN BREAD WHEAT (*TRITICUM AESTIVUM* L.) UNDER LOW AND HIGH NITROGEN CONDITIONS

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ABSTRACT

The development of high-yielding and resource-efficient wheat cultivars through breeding programs is crucial for sustainable agriculture and ensuring global food security. To achieve this objective, present investigation was carried out at S. D. Agricultural University, Sardarkrushinagar, Gujarat during *rabi* 2022-23 by taking 28 bread wheat genotypes (including 7 parents and 21 F_1s) and grown in split plot design under two nitrogen level *i.e.,* N_0 (no nitrogen condition) and N+ (optimal dose of nitrogen). Analysis of correlation coefficients revealed that grain yield per plant showed significant positive correlations with spike length, biological yield per plant (in N_0 and N+ conditions), grains per spike (in N_0 condition), and nitrogen use efficiency, as well as number of tillers per plant and harvest index (in N+ condition). Path analysis showed that biological yield per plant, harvest index, nitrogen content in grain, and nitrogen use efficiency had the highest positive effects on grain yield under respective nitrogen conditions. These traits can be prioritized for direct selection to enhance grain yield and nitrogen use efficiency in wheat breeding programs.
***Keywords*:** Correlation coefficients, Path analysis, Nitrogen use efficiency, Wheat (*Triticum aestivum* L.)

Introduction

Wheat is one of the extremely important cereal crops worldwide and used as a staple food for more than one-third of the world population. Wheat (*Triticum aestivum* L. 2n = 42) is a self-pollinated crop of the member of *Poaceae* family. It is known for its remarkable adoption to a wide range of environments and its role in world economy. 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. The grain yield of wheat has remained suboptimal and much lower than varietal potential, which contributes to food and nutritional insecurity. The decreasing area of agricultural land due to human settlements triggered by the skyrocketing increase in the global population, and the worsening scenario of climate change along with abiotic stresses have been projected to adversely affect C_3 cereals productivity (Afzal *et al*., 2015, Iqbal *et al*., 2018, El Sabagh *et al*., 2019). Among abiotic stresses, suboptimal plant nutrition seriously compromises the growth and development of wheat plants, which leads to a significant reduction in yield despite the presence of favourable agro-climatic conditions. Wheat is regarded to be comparatively more sensitive to suboptimal plant nutrition, which significantly hampers the vegetative growth of crop plants, thereby inducing suppressed reproductive growth phases (Iqbal *et al*., 2018, Siddiqui *et al*., 2019).

As land and water resources are becoming limited, the increase of wheat production can be achieved only by increasing the average yield. This can be accomplished by an increase of the efficiency of fertilizer. Indeed, nitrogen fertilizer constitutes one of the most important agronomic practices in cereals, particularly since the elimination of crop rotations (Crews and Peoples, 2004). The worldwide, synthetic N fertilizer consumption is projected to reach 105 Tg N by 2030 and 135 Tg N by 2050. The N fertilizer consumption has grown dramatically in Asia, about 17-fold in the last 40 years (Pathak *et al*., 2008). Nitrogen constitutes the most important fertilizer for sustaining growth and improving the economic yield in bread wheat (Pang *et al*., 2013). Wheat cultivars respond differently to fertilization regimes, and it has been inferred that superior genotype selected on the basis of better resource use efficiency might facilitate attaining food security and curbing nutrient losses (Siddiqui *et al*., 2019). Iqbal *et al*., (2021) also reported similar findings whereby wheat genotypes performed differently under varying doses of N and concluded that wheat genotypes performed differently in terms of the NUE and grain yield of wheat owing to the varied genetic potential, which was manifested through superior agro-botanical traits.

For improving yield potential with good nitrogen use efficiency Correlation analysis is used as effective tools to determine the relationship among different trait in genetic diverse population for encashment of crop improvement process (Dhami *et al*., 2018). Correlation coefficient provides a better understanding of the different traits with grain yield. The study of association among various traits is useful to breeders in selecting genotypes possessing groups of desired traits. Path coefficient measures the magnitude of direct and indirect contribution of the components characters to a complex character and it has been defined standardized regression coefficient which split the correlation coefficient in to direct and indirect effects. Path coefficient analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve yield (Dewey and Lu 1959, Ahmed *et al*., 2003). The aim of the study is to analyze the relationships among various traits and their direct and indirect effects on grain yield to enhance yield potential with improved nitrogen use efficiency.

Material and Methods

The present investigation was carried out at the S. D. Agricultural University, Sardarkrushinagar. The parental lines received from Wheat Research Station, Vijapur, Gujarat, were crossed in diallel design excluding the reciprocals during *rabi* 2021-22. During *rabi* 2022-23 the twenty-eight entries including 7 parents and 21 F_1s were grown in Split Plot Design with three replications under two nitrogen level *i.e.,* N_0 (no nitrogen condition) and N+ (optimal dose of nitrogen). Each parent and F_1s were sown in two rows; each row was two meter long; spacing between rows were 22.5 cm and 10 cm between plants. All other agricultural practices were done according to the recommendation of Ministry of Agriculture for growing wheat.

Observations were recorded on various characters *viz*., days to flowering, days to maturity, plant height, peduncle length, spike length, grains per spike, number of tillers per plant, 1000 grains weight, leaf chlorophyll content, grain yield per plant, biological yield per plant, harvest index, nitrogen content in leaves, nitrogen content in grain, protein content in grain, canopy temperature after 5 days and 15 days of anthesis, nitrogen use efficiency. The trait nitrogen use efficiency (NUE) was calculated as per formula suggested by Gohain *et al*. (2020).

$$\text{NUE}(\%) = \frac{\begin{array}{c}\text{Grain yield in N + condition}\\ \text{- Grain yield in N0 condition}\end{array}}{\text{Total nitrogen supply }(\text{N}_a)} \times 100$$

Where, N+ is the grain yield per plant at 120 kg N/ha, N_0 is the grain yield per plant at 0 kg N/ha, and N_a is the quantity of nitrogen applied, *i.e.,* 120 kg/ha.

The mean values of all characters were subjected to statistical analysis using different approaches. The Correlation coefficients between different characters were estimated according to Karl Pearson's (1896) method and path coefficient analysis was carried out according to Dewey and Lu (1959).

Result and Discussion

Correlation coefficients

The relationship between yield and its contributing traits was examined through correlation analysis. Genotypic and Phenotypic correlation coefficients among the eighteen traits of 28 wheat genotypes under varying nitrogen conditions presented in Table 1 and 2 respectively. Correlation analysis revealed that, under both nitrogen (N_0 and N+) condition, the values of genotypic correlations were higher than their corresponding phenotypic correlations for most of the traits under study. It indicated that there was a high degree of association between two respective variables at genotypic level, while its phenotypic expression was deflated by the influence of environment. The phenotypic correlation coefficients in very few cases were higher than their corresponding genotypic correlation coefficients which might be due to the non-genetic causes; probably environment influenced the value of phenotypic correlation.

Under N_0 condition

In N_0 condition, grain yield per plant was highly significant and positively correlated with spike length (r_g = 0.842** and r_p = 0.498**), grains per spike (r_g = 0.685** and r_p = 0.485**) and biological yield per plant (r_g = 0.611** and r_p = 0.716**) at genotypic and phenotypic levels. These observations are in agreement with the earlier reports of Aga *et al.*, (2022). On the other hand, nitrogen use efficiency showed negative and significant correlation with plant height (r_g = -0.415* and r_p = -0.384**) at both levels, this inverse relationship indicating that selection of those genotypes which showed low plant height leads to increasing the nitrogen use efficiency and *vice-versa*.

In addition to this, spike length showed a highly significant and positive correlation with grains per spike (r_g = 0.842** and r_p = 0.498**), biological yield per plant (r_g = 0.787** and r_p = 0.465**) at genotypic and phenotypic levels. It revealed that as length of spike increase the numbers of grains per spike and biological yield per plant were also increased thereby plant will have a positive impact on grain yield. Grains per spike had a positive and highly significant association with biological yield per plant (r_g = 0.679** and r_p = 0.555**), nitrogen content in leaves (r_g = 0.456* and r_p = 0.372**) at both genotypic and phenotypic level. These advantageous association indicates higher grains per spike contribute positively to overall yield, biomass production and nutrient accumulation in leaves, highlighting their importance in enhancing crop yield and nutrient uptake efficiency.

Under N+ condition

In N+ condition, grain yield per plant and nitrogen use efficiency were highly significant and positively correlated with spike length, number of tillers per plant, biological yield per plant and harvest index. In addition to this, grain yield per plant and nitrogen use efficiency were also exhibited highly significant and positive correlation (r_g = 0.970** and r_p = 0.959**). This result highlights the critical role of nitrogen use efficiency in achieving higher grain yield per plant, emphasizing the need for targeted efforts in crop breeding to optimize nitrogen utilization and improve yield potential.

Spike length expressed highly significant and positive association with biological yield per plant (r_g = 0.962** and r_p = 0.334**), grains per spike (r_g = 0.664**), number of tillers per plant (r_g = 0.666**), nitrogen content in leaves (r_g = 0.608**). Which reveals that increase in spike length also increase grains per spike and biological yield per plant which ultimately gives positive impact on grain yield per plant. Similar results were observed in the work of Biradar *et al.* (2024).

Grains per spike expressed positive and highly significant association with nitrogen content in grain (r_p = 0.301**) whereas negative significant association nitrogen content in leaves (r_p = -0.268*) at phenotypic level. This interrelationship indicated that higher grains per spike may be associated with enhance nitrogen content in grain with reduced nitrogen content in leaves, possibly indicating nutrient redistribution towards grain development. Number of tillers per plant showed highly significant and positive correlations with biological yield per plant (r_g = 0.776** and r_p = 0.622**) at both levels, highlighting their importance in enhancing crop yield.

Path coefficients

Coefficient of correlation measures the degree and association between two characters. However, this may not give true picture under complex situation. Under such conditions, path coefficient analysis provides a means of measuring the direct as well as indirect effect via other variables on the end product by partitioning correlation coefficients. The direct and indirect effects on grain yield were estimated for all characters under study, which provided a better index for selection. (Kumar *et al.*, 2018).

The results show that under N_0 condition, highest positive direct effect towards the grain yield per plant was observed by biological yield per plant followed by harvest index and nitrogen content in grain. Similarly in N+ condition, biological yield per plant has highest direct and positive effect followed by harvest index and nitrogen use efficiency on grain yield per plant. Biological yield per plant indirectly contributes to grain yield per plant through positive effects on spike length, number of grains per spike, number of tillers per plant and nitrogen content in leaf under both nitrogen conditions (N_0 and N+). Additionally, it influences grain yield via chlorophyll content under N_0 conditions and nitrogen use efficiency under N+ conditions. The residual effect determines how best the causal factors account for the variability of the resultant factor, the yield per plant. In the present study the residual effect was 0.00 and 0.01 (N_0 and N+ respectively) was considerably low, indicating an appropriate explanation of the characters under study and a high contribution of independent traits to the dependent traits (grain yield per plant) as shown in table 3 and 4. These findings are in confirmation with Baye *et al.* (2020), Tarkeshwar *et al.* (2020), Saha *et al.* (2018), Alemu *et al.* (2020) and Choudhary *et al.* (2021).

Table 1: Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient analysis for various traits under the N_0 (no nitrogen) condition

	DF	DM	PH	PL	SL	GPS	T/P	TW	BY	HI	PG	NG	NL	CC	CT-1	CT-2	NUE	GY
DF		0.564**	0.257	-0.674**	0.275	0.294	0.013	-0.277	0.23	-0.764**	-0.275	0.389*	0.412*	0.637**	0.061	0.382*	-0.277	-0.014
DM	0.153		0.104	0.261	0.402*	0.239	-0.084	0.591**	0.071	-0.864**	0.201	-0.122	-0.16	0.642**	0.772**	-0.737**	0.207	-0.166
PH	0.205	0.098		-0.059	0.959**	0.671**	0.174	-0.026	0.601**	0.274	0.033	-0.079	0.179	0.034	-0.886**	-0.501**	-0.407*	0.714**
PL	-0.489**	0.007	-0.066		0.106	-0.091	-0.045	0.671**	-0.135	0.754**	0.453*	-0.075	-0.155	-0.134	0.141	-0.214	0.087	0.134
SL	0.123	0.029	0.423**	0.068		0.842**	0.245	0.386*	0.787**	-0.304	0.299	0.015	0.09	0.376*	-0.380*	-0.155	-0.378*	0.709**
GPS	0.260*	0.211	0.436**	-0.078	0.498**		0.023	0.144	0.679**	-0.144	0.064	0.18	0.456*	0.272	0.243	-0.636**	-0.389*	0.685**
T/P	0.084	0.072	0.163	-0.058	0.079	0.038		-0.033	0.242	-0.389*	-0.087	0.2	-0.038	-0.169	-0.669**	-0.37	0.213	0.144
TW	-0.201	0.174	-0.038	0.387**	0.076	0.068	0.027		-0.028	-0.158	0.351	-0.444*	-0.232	0.05	0.583**	-0.567**	-0.297	-0.067
BY	0.145	0.095	0.486**	-0.078	0.465**	0.555**	0.127	-0.03		-0.35	-0.057	-0.091	0.419*	0.145	-0.627**	-0.089	-0.324	0.611**
HI	-0.235*	-0.061	0.065	0.037	-0.133	-0.03	0.051	0.193	-0.243*		0.25	0.123	-0.357	-0.917**	0.553**	0.133	-0.249	0.093
PG	-0.104	0.003	-0.009	0.087	0.232*	0.022	-0.225*	0.175	-0.061	-0.004		0.067	-0.308	0.153	0.589**	0.431*	-0.184	-0.009
NG	0.230*	0.127	-0.057	-0.229*	0.003	0.08	0.081	-0.078	-0.006	0.192	0.142		0.204	0.338	0.112	0.071	0.359	-0.007
NL	0.238*	-0.08	0.133	-0.096	0.079	0.372**	0.049	-0.202	0.312**	-0.078	-0.124	0.039		0.085	0.159	-0.01	0.148	0.329
CC	0.499**	0.236*	0.04	-0.128	0.208	0.208	-0.118	0.058	0.115	-0.247*	0.112	0.215*	0.098		0.705**	0.08	-0.057	-0.142
CT-1	0.076	-0.049	-0.153	0.05	-0.065	-0.04	-0.174	0.019	-0.138	-0.013	0.079	0.009	0.006	0.222*		-0.864**	-0.215	-0.490**
CT-2	0.073	0.029	0.071	-0.103	-0.054	-0.142	-0.075	-0.232*	-0.046	0.091	0.091	0.02	-0.013	0.007	0.154		-0.538**	-0.037
NUE	-0.235*	0.044	-0.320**	0.0424	-0.193	-0.327**	0.147	-0.161	-0.309**	-0.142	-0.142	0.224*	0.112	-0.038	-0.072	-0.187		-0.037
GYP	-0.039	0.033	0.485**	-0.013	0.325**	0.485**	0.157	0.117	0.716**	0.489**	-0.051	0.16	0.228*	-0.076	-0.113	-0.005	-0.005	

Table 2: Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient analysis for various traits under the N^{+} (recommended dose of nitrogen) condition

	DF	DM	PH	PL	SL	GPS	T/P	TW	BY	HI	PG	NG	NL	CC	CT-1	CT-2	NUE	GY
DF		0.101	-0.062	-0.718**	0.817**	0.376*	0.14	-0.246	0.052	-0.531**	0.729**	0.571**	-0.126	0.239	-0.049	0.084	-0.364	-0.359
DM	0.239*		0.07	0.161	-0.494**	-0.046	0.082	0.916**	0.494**	-0.647**	0.828**	0.415*	0.266	0.05	-0.708**	-0.886**	0.128	0.011
PH	0.038	0.018		0.163	0.281	0.04	0.385*	0.034	0.470*	-0.364	0.139	0.111	0.063	-0.031	-0.094	-0.148	0.087	0.116
PL	-0.477**	0.074	0.131		-0.446*	-0.252	-0.105	0.221	0.151	0.011	-0.242	-0.425*	-0.019	-0.22	0.153	-0.011	0.228	0.135
SL	0.161	0.153	0.156	-0.11		0.664**	0.666**	-0.846**	0.962**	-0.105	0.204	0.368	0.608**	0.075	-0.349	-0.501**	0.779**	0.789**
GPS	0.183	-0.034	0.054	-0.168	0.201		0.05	-0.639**	0.176	-0.102	0.01	0.359	-0.29	-0.458*	-0.279	-0.049	0.033	0.072
T/P	0.066	0.039	0.146	-0.068	0.157	0.037		-0.344	0.776**	-0.098	0.016	-0.062	0.148	-0.012	0.178	-0.278	0.547**	0.602**
TW	-0.318**	0.119	0.089	0.194	0.137	-0.258*	-0.088		-0.021	-0.175	-0.048	-0.089	0.098	0.152	-0.064	-0.781**	-0.12	-0.144
BY	0.022	0.119	0.310**	0.139	0.334**	0.13	0.622**	0.003		-0.298	0.031	-0.012	0.203	-0.085	-0.099	-0.679**	0.622**	0.634**
HI	-0.272*	-0.213	-0.147	-0.002	0.013	-0.057	-0.088	-0.064	-0.355*		-0.247	-0.292	0.109	0.352	0.234	0.420*	0.523**	0.543**
PG	0.263*	0.222*	-0.033	-0.162	0.142	0.047	-0.018	-0.029	0.039	-0.211		0.583**	0.233	0.501**	-0.24	-0.142	0.27	-0.15
NG	0.419**	0.156	0.139	-0.301**	0.15	0.301**	-0.051	-0.023	0.06	-0.197	0.418**		0.028	0.312	-0.194	-0.217	-0.179	-0.241
NL	-0.03	0.123	0.085	-0.026	0.2	-0.268*	0.109	0.07	0.208	0.049	0.195	0.075		0.538**	-0.013	-0.002	-0.084	0.264
CC	0.059	0.057	0.03	-0.142	0.098	-0.289**	-0.009	0.084	-0.052	0.278*	0.425**	0.260*	0.410**		-0.019	0.175	0.231	0.19
CT-1	-0.013	-0.295**	-0.026	0.116	-0.117	-0.176	0.081	-0.072	-0.092	0.186	-0.152	-0.129	0.022	0.09		0.23	0.113	0.063
CT-2	-0.059	-0.2	-0.17	-0.055	0.002	-0.077	-0.195	-0.152	-0.336**	0.256*	0.025	-0.133	-0.03	0.053	0.075		-0.192	-0.27
NUE	-0.226*	-0.009	0.087	0.2	0.310**	0.032	0.435**	-0.05	0.580**	0.503**	0.230*	-0.073	-0.076	0.2	0.084	-0.101		0.970**
GYP	-0.214	-0.045	0.14	0.124	0.320**	0.064	0.488**	-0.05	0.608**	0.518**	-0.128	-0.117	0.230*	0.176	0.052	-0.097	0.959**	

Note: * and ** indicate level of significance at 5 % and 1 %, respectively

(DF = Days to flowering, DM = Days to maturity, PH = Plant height, PL = Peduncle length, SL = Spike length, GPS = Grains per spike, T/P = Number of tillers per plant, TW = 1000 grain weight, BY = Biological yield per plant, HI = Harvest index, PG = Protein content in grain, NG = Nitrogen content in grain, NL = Nitrogen content in leaves, CC = Leaf chlorophyll content, CT-1 = Canopy temperature after 5 days of anthesis, CT-2 = Canopy temperature after 15 days of anthesis, NUE = Nitrogen use efficiency, GYP = Grain yield per plant)

Table 3 : Direct and indirect effects of various traits under the N_0 (no nitrogen) condition

	DF	DM	PH	PL	SL	GPS	T/P	TW	BY	HI	PG	NG	NL	CC	CT-1	CT-2	NUE	Genotypic correlation of GY
DF	**0.0693**	-0.0065	0.0207	-0.0200	-0.0198	-0.0662	-0.0003	-0.0084	0.2835	-0.2707	-0.0161	0.0585	-0.0005	-0.0248	0.0040	-0.0388	0.0222	-0.014
DM	0.0391	**-0.0115**	0.0084	0.0077	-0.0289	-0.0539	0.0017	0.0179	0.0871	-0.3060	0.0063	-0.0184	0.0003	-0.0250	0.0513	0.0748	-0.0166	-0.166
PH	0.0178	-0.0012	**0.0808**	-0.0018	-0.0691	-0.1513	-0.0036	-0.0008	0.7418	0.0971	-0.0070	-0.0118	0.0001	-0.0013	-0.0589	0.0509	0.0326	0.714**
PL	-0.0467	-0.0030	-0.0048	**0.0296**	-0.0076	0.0206	0.0009	0.0203	-0.1667	0.2669	0.0061	-0.0113	0.0008	0.0052	0.0094	0.0217	-0.0070	0.134
SL	0.0191	-0.0046	0.0775	0.0031	**-0.0721**	-0.1896	-0.0051	0.0117	0.9710	-0.1077	-0.0035	0.0022	0.0005	-0.0147	-0.0253	0.0158	0.0303	0.709**
GPS	0.0204	-0.0027	0.0542	-0.0027	-0.0606	**-0.2253**	-0.0005	0.0044	0.8381	-0.0509	-0.0179	0.0272	0.0001	-0.0106	0.0162	0.0645	0.0312	0.685**
T/P	0.0009	0.0010	0.0141	-0.0013	-0.0177	-0.0053	**-0.0206**	-0.0010	0.2981	-0.1377	0.0015	0.0301	-0.0002	0.0066	-0.0445	0.0376	-0.0170	0.144
TW	-0.0192	-0.0068	-0.0021	0.0199	-0.0278	-0.0325	0.0007	**0.0303**	-0.0349	-0.0560	0.0091	-0.0668	0.0006	-0.0019	0.0388	0.0576	0.0238	-0.067
BY	0.0159	-0.0008	0.0486	-0.0040	-0.0567	-0.1531	-0.0050	-0.0009	**0.9337**	-0.1241	-0.0164	-0.0137	-0.0001	-0.0056	-0.0417	0.0091	0.0260	0.611**
HI	-0.0530	0.0099	0.0221	0.0223	0.0219	0.0324	0.0080	-0.0048	-0.4323	**0.3542**	0.0140	0.0186	0.0004	0.0357	0.0368	-0.0135	0.0200	0.093
PG	0.0286	0.0018	0.0144	-0.0046	-0.0065	-0.1027	0.0008	-0.0070	0.5168	-0.1266	**-0.0392**	0.0306	-0.0005	-0.0033	0.0106	0.0010	0.0147	-0.009
NG	0.0269	0.0014	-0.0063	-0.0022	-0.0011	-0.0406	-0.0041	-0.0134	-0.1122	0.0437	-0.0080	**0.1506**	0.0001	-0.0132	0.0074	-0.0073	-0.0288	-0.007
NL	-0.0191	-0.0023	0.0027	0.0134	-0.0216	-0.0144	0.0018	0.0106	-0.0703	0.0886	0.0120	0.0101	**0.0017**	-0.0059	0.0392	-0.0437	-0.0119	0.329
CC	0.0442	-0.0074	0.0027	-0.0040	-0.0271	-0.0612	0.0035	0.0015	0.1784	-0.3247	-0.0033	0.0509	0.0003	**-0.0389**	0.0469	-0.0081	0.0046	-0.142
CT-1	0.0042	-0.0088	-0.0716	0.0042	0.0274	-0.0548	0.0138	0.0176	-0.7733	0.1960	-0.0062	0.0168	0.0010	-0.0274	**0.0665**	0.0877	0.0173	-0.490**
CT-2	0.0265	0.0084	-0.0405	-0.0064	0.0112	0.1433	0.0076	-0.0172	-0.1102	0.0471	0.0004	0.0108	0.0007	-0.0031	-0.0574	**-0.1015**	0.0432	-0.037
NUE	-0.0192	-0.0024	-0.0329	0.0026	0.0272	0.0877	-0.0044	-0.0090	-0.4003	-0.0881	0.0072	0.0540	0.0003	0.0022	-0.0143	0.0546	**-0.0802**	-0.037

Residual Value = 0.0

(DF = Days to flowering, DM = Days to maturity, PH =Plant height, PL = Peduncle length, SL = Spike length, GPS = Grains per spike, T/P = Number of tillers per plant, TW = 1000 grain weight, BY = Biological yield per plant, HI = Harvest index, PG = Protein content in grain, NG = Nitrogen content in grain, NL= Nitrogen content in leaves, CC = Leaf chlorophyll content, CT-1 = Canopy temperature after 5 days of anthesis, CT-2 = Canopy temperature after 15 days of anthesis, NUE = Nitrogen use efficiency, GYP = Grain yield per plant)

Table 4: Direct and indirect effects of various traits under the N+ (recommended dose of nitrogen) condition

	DF	DM	PH	PL	SL	GPS	T/P	TW	BY	HI	PG	NG	NL	CC	CT-1	CT-2	NUE	Genotypic correlation of GY
DF	**-0.1741**	0.0021	0.0015	0.1573	-0.0487	-0.0158	-0.0231	0.0245	0.0497	-0.3210	0.0037	-0.0253	0.0855	-0.0073	-0.0016	0.0032	-0.0695	-0.359
DM	-0.0176	**0.0203**	-0.0016	-0.0353	0.0295	0.0019	-0.0135	-0.0914	0.4724	-0.3911	-0.0078	-0.0184	0.0971	-0.0015	-0.0227	-0.0340	0.0244	0.011
PH	0.0109	0.0014	**-0.0235**	-0.0357	-0.0168	-0.0017	-0.0634	-0.0034	0.4495	-0.2203	-0.0018	-0.0049	0.0163	0.0010	-0.0030	-0.0057	0.0167	0.116
PL	0.1250	0.0033	-0.0038	**-0.2189**	0.0266	0.0106	0.0173	-0.0220	0.1444	0.0064	0.0006	0.0189	-0.0284	0.0067	0.0049	-0.0004	0.0436	0.135
SL	-0.1422	-0.0100	-0.0066	0.0976	**-0.0596**	-0.0280	-0.1096	0.0844	0.9205	-0.0637	-0.0179	-0.0163	0.0239	-0.0023	-0.0112	-0.0192	0.1488	0.789**
GPS	-0.0654	-0.0009	-0.0009	0.0551	-0.0396	**-0.0421**	-0.0082	0.0637	0.1688	-0.0619	0.0085	-0.0159	0.0012	0.0140	-0.0089	-0.0019	0.0063	0.072
T/P	-0.0244	0.0017	-0.0091	0.0231	-0.0397	-0.0021	**-0.1646**	0.0343	0.7424	-0.0594	-0.0044	0.0028	0.0019	0.0004	0.0057	-0.0107	0.1045	0.602**
TW	0.0428	0.0186	-0.0008	-0.0484	0.0505	0.0269	0.0566	**-0.0997**	-0.0203	-0.1060	-0.0029	0.0039	-0.0057	-0.0046	-0.0021	-0.0300	-0.0229	-0.144
BY	-0.0091	0.0100	-0.0111	-0.0330	-0.0574	-0.0074	-0.1277	0.0021	**0.9567**	-0.1799	-0.0060	0.0005	0.0036	0.0026	-0.0032	-0.0261	0.1189	0.634**
HI	0.0924	-0.0131	0.0086	-0.0023	0.0063	0.0043	0.0162	0.0175	-0.2847	**0.6045**	-0.0032	0.0130	-0.0290	-0.0107	0.0075	0.0161	0.1000	0.543**
PG	0.0219	0.0054	-0.0015	0.0043	-0.0362	0.0122	-0.0244	-0.0098	0.1943	0.0660	**-0.0294**	-0.0012	0.0274	-0.0164	-0.0004	-0.0001	0.0515	-0.15
NG	-0.0994	0.0084	-0.0026	0.0931	-0.0219	-0.0151	0.0103	0.0089	-0.0110	-0.1766	-0.0008	**-0.0443**	0.0684	-0.0095	-0.0062	-0.0083	-0.0342	-0.241
NL	-0.1268	0.0168	-0.0033	0.0530	-0.0122	-0.0004	-0.0026	0.0048	0.0295	-0.1495	-0.0069	-0.0259	**0.1173**	-0.0153	-0.0077	-0.0055	-0.0160	0.264
CC	-0.0416	0.0010	0.0007	0.0481	-0.0045	0.0193	0.0019	-0.0151	-0.0816	0.2125	-0.0158	-0.0138	0.0588	**-0.0305**	-0.0006	0.0067	0.0441	0.19
CT-1	0.0084	-0.0144	0.0022	-0.0334	0.0208	0.0117	-0.0294	0.0064	-0.0947	0.1415	0.0004	0.0086	-0.0282	0.0006	**0.0320**	0.0088	0.0216	0.063
CT-2	-0.0147	-0.0180	0.0035	0.0025	0.0299	0.0021	0.0458	0.0778	-0.6498	0.2538	0.0001	0.0096	-0.0167	-0.0054	0.0074	**0.0384**	-0.0366	-0.27
NUE	0.0633	0.0026	-0.0021	-0.0500	-0.0465	-0.0014	-0.0900	0.0120	0.5955	0.3164	-0.0079	0.0079	-0.0098	-0.0071	0.0036	-0.0074	**0.1910**	0.970**

Residual Value = 0.01

(DF = Days to flowering, DM = Days to maturity, PH =Plant height, PL = Peduncle length, SL = Spike length, GPS = Grains per spike, T/P = Number of tillers per plant, TW = 1000 grain weight, BY = Biological yield per plant, HI = Harvest index, PG = Protein content in grain, NG = Nitrogen content in grain, NL= Nitrogen content in leaves, CC = Leaf chlorophyll content, CT-1 = Canopy temperature after 5 days of anthesis, CT-2 = Canopy temperature after 15 days of anthesis, NUE = Nitrogen use efficiency, GYP = Grain yield per plant)

Conclusion

The overall results revealed that at both genotypic and phenotypic level, significant positive correlation was observed for grain yield per plant with spike length, biological yield per plant under both N condition (N_0 and N+). Additionally, number of grains per spike in N_0 and nitrogen use efficiency along with number of tillers per plant and harvest index in N+ also showed positive significant correlations with grain yield. This result suggested that these characters can be improved simultaneously with grain yield per plant by direct selection. The interrelationship among yield components traits would helpful in future breeding programmes for increasing the grain yield levels with nitrogen use efficiency

From path analysis we concluded that some traits *viz.,* biological yield per plant, harvest index, nitrogen content in grain and nitrogen use efficiency exhibited highest positive effect on grain yield under respective nitrogen conditions and therefore, more emphasis should be given to these component traits while implementing selection criteria for crop improvement programme in bread wheat.

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