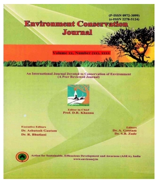
Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Study of correlation and path coefficient analysis for yield attributing traits in selected rils of diverse wheat (*Triticum aestivum* L.) genotypes for heat tolerance

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ARTICLE INFO

Received : 28 August 2022
Revised : 27 November 2022
Accepted : 05 December 2022

Available online: 09 March 2023

Key Words:
Chlorophyll content
Correlation
Grain yield
Path coefficient
Relative water loss

ABSTRACT

Rising temperature has adversely affected wheat production globally. In this realm we studied various morpho-physiological traits governing heat tolerance using thirty bread wheat RILs developed via crossing LOK-1 x HUW- 468, LOK 1 x HUW 234 and Raj-4014 x PBN-51. Correlation studies reflected that traits like number of tillers per plant, plant height, and chlorophyll content were significantly positive correlated with grain yield per plant, on the other hand path coefficient analysis revealed that the chlorophyll content (0.362) and tillers per plant (0.222) showed a significant positive correlation with grain yield per plant, whereas significant negative correlation for grain yield was exhibited with relative water loss (-0.392) and canopy temperature (-0.402) at genotypic level.

Introduction

Bread wheat (*Tritium aestivum* L.) being a hexaploid (AABBDD) is an annual *Rabi* crop of vital importance among staple food crops globally. Wheat, a multipurpose crop is a primary source of gluten (protein) for diverse range of world population. Global warming, a cataract in the world eye via which a nebulae of abiotic as well as biotic stresses have cruised their way out. Abiotic stresses such as high temperature stress (20%), salinity stress (10%), drought stress (9%), and chilling stress (7%) retard wheat grain yield in the manner of 50% cumulatively (Thilert *et al.,* 2006). Among the wholesome of the abiotic stresses, heat stress is of prime importance as it limits crop production via hampering plant development and simultaneously hitting crop yield. With the rise of a unit degree global temperature, as much as 4 million tonnes of global wheat production is retarded (Khairnar *et al.,* 2018). Heat tolerance refers to a plant's capacity to produce desirable yield under elevated temperature environment by combating higher temperatures (Thapa *et al.,* 2020). The consequences of extreme temperatures on crop growth depends on various factors like temperature intensity, duration of high temperature, development stage and the interaction of these factors with the growth stage (Wahid *et*

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Doi:https://doi.org/10.36953/ECJ.14692452

al., 2007). High temperature stress reduces number of kernels per ear and the weight of kernel hence affecting grain yield per plant (Gupta *et al.,* 2001). Direct exposure to high temperature leads to chlorophyll degradation that in turn hampers grain yield (Tripathy *et al.,* 2012), also, loss of chlorophyll content damages cell membrane and ultimately leads to leaf senescence (Ristic *et al.,* 2007).Grain yield is not only pretentious to environmental factors but also lies on numerous yield attributing characters which fluctuate yield in even Steven manner. To study the influence of each of these independent traits affecting the grain yield and hence provide a criterion for the selection of the desirable genotypes emphasis is laid on the correlations as well as path correlation (Chowdhury *et al.,* 2019). The correlation coefficient assesses the degree of similarity between any two characters and. hence is vital for calculating the dependence of grain yield on these characters as well as between other characters. However, the study of correlation coefficients alone does not meet the requirements and thus is insufficient to explain the relationships between different traits because it is not able to evaluate the direct and indirect effects of independent variables on dependent variables. To overcome these limitations, path coefficient analysis is used to evaluate the effect of each independent variable (cause) on the dependent variable (effect), i.e. yield (Abdulhamed *et al.,* 2021). The current study was undertaken to ascertain the correlation and the direct and indirect effects of twelve morph-physiological variables on yield.

Material and Methods

Plant material and field trails

The present study was conducted at the Research Farm of Division of Plant Breeding and Genetics, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha. A population of advanced Recombinant Inbred Lines was used as the germplasm for the current investigation. 30 RILs derived from three crosses between LOK-1 × HUW- 468, LOK 1 × HUW 234 and Raj-4014 × PBN-51 along with two checks namely PBN 51 (heat tolerant) and HUW 234 (heat susceptible) line were used. Among these, LOK -1 and PBN-51 were used as heat-tolerant lines while as HUW-234, HUW-468, and Raj-4014 were used as heat susceptible lines. Ten selected genotypes from these crosses were planted during *Rabi* 2018-2019 using RBD design.The maximum temperature of 43.1ºC was recorded in the fourth week of the May, while as the lowest temperature of 1.7ºC was recorded in the last week of December. Among the total tally of days of the crop stand, as many as 77 days were recorded with temperatures above 25ºC. Fortunately, or unfortunately, these days of high temperature coincided with the most sensitive stage of crop growth that are flowering and grain filling stages, which directly determine yield. Correlation analysis was performed with windostat using Pearson's correlation coefficient method at both 5% and 1% levels of significance. (*P<0.05, **P<0.01).

Results and Discussion

Character association

The correlation coefficient analysis of different trait is presented in table 1 for genotypic and phenotypic correlations respectively.Grain yield per plant showed positive correlation with plant height (0.036), number of tillers per plant (0.222) and flag leaf area (0.064) at genotypic level. Similarly, Majoul *et al.* (2004) observed positive correlation of grain yield with similar characters. Grain yield showed positive correlation with yield at phenotypic level (0.026). (Akram. 2011) concluded significant positive correlation of yield with relative water content. According to (Molnar *et al.,* 2002), a decline in relative water content causes a decrease in plant yield. Wheat genotypes' leaf water capacities were examined by Ashraf *et al*. (1994), who came to the conclusion that cultivars with higher water retention capacities were more heat-tolerant. A cooler canopy reduces the detrimental effects of heat stress on grain yield, as seen by the canopy temperature's strong negative association with grain yield at genotypic level (-0.402) in current experiment. Grain yield was found to be significantly negatively correlated with both canopy temperature (-0.402) and relative water loss (-0.392) at genotypic level. Reduced canopy temperature during crucial stages, such as the grain filling stage, is a crucial physiological trait to take into account when breeding for high-temperature tolerant cultivars (Munjal and Rena's 2003). According to Zhang and Oweis (1998), optimal leaf water during or after anthesis enhances photosynthetic rate and aids in the transfer of carbohydrates to grains, improving grain quality and increasing yield. (Bahar *et al.,* 2008) for canopy temperature and Khazaei *et al*. (2010) for relative water loss, also produced similar findings. Relative water loss shows negative correlation relation with grain yield (Kashik *et al.,* 2004). Relative water content showed a positive correlation with test weight (0.221) and tillers per plant (0.194) at genotypic level. Similar to our findings, Jaiswal *et al*. (2010) similarly observed positive correlation between tillers per plant and relative water content. Chlorophyll content showed a genotypically significant positive correlation with flag leaf area (0.221), tillers per plant (0.537) and relative water content (0.065). A substantial positive correlation between flag leaf area and the number of tillers per plant with chlorophyll content, as well as a positive association with relative water content at the genotypic level, was observed by Ali *et al*. in 2008. Significant amount of significant positive correlation was observed between number of days to maturity with tillers per plant and flag leaf area, as well as a positive correlation with canopy temperature at the genotypic level. In accordance with our findings, Anwar *et al*. (2009) reported similar results for tillers per plant. Compared to significant negative correlation with days to 50% blooming (-0.338), thousand grain weight showed positive correlation with chlorophyll concentration (0.019) and positive significant correlation with relative water content (0.221) at genotypic level. Asif *et al.* (2003) also concluded same results for relative water content. Flag leaf area displayed significant positive association with height of plant (0.244), relative water content (0.309), tillers per plant (0.529), and chlorophyll content (0.275), whereas negative correlation with canopy temperature (0.024) at genotypic level. Leaf area increases the contribution to canopy temperature. More is the leaf area index, more is the area of leaf, a greater photo-synthetically active surface area is available, which would result in high production rate**.** This showed that increase in leaf area index declines canopy temperature because canopy of plants increases with increase in flag leaf area which improves transpiration rate and assists in lowering down the canopy temperature and maintaining cooler temperature than ambient temperature.

Therefore, it can be inferred from the current study that there is a positive association between flag leaf area and grain output, and significant positive correlation between plant height, chlorophyll content and number of tillers per plant with grain yield. For an increase in grain yield, choosing any one of these physio-morphological characteristics would be crucial.

Path coefficient analysis

In the current experiment path coefficient studies were performed for grain yield. Genotypic path diagram of yield attributing characters on grain yield in wheat for thirty-two wheat genotypes is presented in fig 1. The direct and indirect effect of different component characters and physiological characters with grain yield per plant at genotypic level are tabulated in table 2. Since, the correlation studies alone are not sufficient to study association analysis very clear, hence the study of real effect of an independent character towards grain yield per plant becomes essential. Correlation studies cannot interpret the precise results predicted by path coefficient. Path correlation considers both the direct and indirect effects of one independent variable on the dependent variable, such as the effect of yield through other indirect factors. In the present experiment study of path coefficient analysis in which diagonal values are direct effects and non-diagonal indirect effects, showed that the flag leaf area (1.470) had highest positive direct effect on grain yield followed by plant height (0.742), number of days to fifty percent flowering (0.185) and number of days to maturity (0.104). Similar results were obtained by Kashif *et al.* (2004) for flag leaf area and plant height. The negative direct effect was recorded for canopy temperature (-0.046), relative water content (-0.463), chlorophyll content (-0.599), grains per ear (-0.381), tillers per plant (-1.680), relative water loss (-0.491) and canopy temperature depression (-1.100). Alike results were reported by Ojha *et al.,* (2018) for chlorophyll content and thousand grain weight, Kashif *et al.* (2004) for number of tillers per plant and Saleem *et al.* (2015) for relative water loss. Characters *viz* canopy temperature, chlorophyll content, flag leaf area and days to maturity showed indirect positive effect via relative water loss. Relative water content and days to maturity showed positive indirect effect via canopy

Table 1: **Genotypic (upper diagonal) and Phenotypic correlations (lower diagonal) coefficient among thirteen characters with grain yield**

	Number of days to fifty percent flowering	Number of days to maturity	Plant height (cm)	Number of tillers per plant	Number of grains per ear	Thousand grain weight (g)	Flag leaf area (cm^2)	Chlorophyll content (SPAD Unit)	Relative water content (%)	Relative water loss (%)	Canopy temperature (^{0} C)	Canopy temperature depression (^{0}C)	Grain yield $^{-1}$ (g)
Number of days to fifty percent flowering		0.474**	0.059	0.186	0.123	-0.338**	-0.047**	0.153	0.026	-0.287**	0.134	-0.011	-0.009
Number of days to maturity	--0.269**		0.062	0.324**	-0.089	-0.324**	0.350**	-0.085	0.241*	0.191	0.060	0.226*	-0.152
Plant height (cm)	0.078	-0.073		0.709**	-0.264*	0.148	0.244	0.320**	0.474**	-0.489**	-0.173	-0.534**	0.367**
Number of tillers per plant	0.243*	0.145	0.318**		-0.029	0.384**	0529**	0.537**	0.194	-0.370**	0,024	-0.478**	0.222*
Number of grains per ear	0.087	0.179	-0.149	0.002		-0.227*	0.360**	-0.664**	-0.157	0.605**	0.249*	0.007**	-0.799**
Thousand grain weight (g)	-0.217*	-0.142	0.157	-0.124	0.1[illegible]		-0.087	0.019	0.221*	0.321*	0.134	-0.040	-0.197
Flag leaf area (cm^2)	-0.053	0.19	0.182	0.303**	0.142	0.069		0.275**	0.309**	0.513**	-0.089	0.076	0.064
Chlorophyll content (SPAD Unit)	0.052	0.055	0.075	0.188	-0.08	0.043	0.026 *		0.082	-0.617**	0.310**	-0.646	0.362**
Relative water content (%)	0.104	0.15	0.248*	0.265**	-0.082	0.105	0.216 *	0.051		0.065	-0.042	-0.084	-0.008
Relative water loss (%)	-0.099	-0.005	-0.055	0.215*	0.178	0.17	0.187	-0.222*	0.067		-0.350**	0.744**	-0.392**
Canopy temperature (^{0} C)	0.111	0.107	-0.105	0.088	0.226*	0.078	0.084	0.066	0.052	-0.044		-0.073	-0.402**
Canopy temperature depression (^{0} C)	0.027	0.211*	-0.154	-0.028	0.286**	-0.094	-0.082	-0.203*	-0.016	0.234*	0.113		-0.857*
Grain yield $^{-1}$ (g)	0.037	-0.041	0.194	0.116	-0.326**	-0.774	0.003	0.166	0.026	-0.235*	-0.174	-0.409**	

***,** significantly at 5% and 1% levels, respectively**

Table 2: Genotypic path showing direct (diagonal) and indirect (off diagonal) effect of twelve characters on grain yield for 32 wheat genotype at phenotypic level

	Canopy temperature (^{0}C)	Plant height (cm)	Relative water content (%)	Chlorophyll content (SPAD Unit)	Number of Grains per ear	Number of tillers per plant	Flag leaf area (cm^2)	Relative water loss (%)	Canopy temperature depression (^{0}C)	Number of days to fifty percent flowering	Number of days to maturity	Thousand grain weight (g)	Genotypic correlation with Grain yield^{-1}
Canopy temperature (^{0}C)	**-0.046**	-0.128	0.020	-0.186	-0.095	-0.041	-0.130	0.172	0.081	0.025	0.006	-0.078	-0.402**
Plant height (cm)	0.008	**0.742**	-0.219	-0.191	0.101	-1.191	0.359	0.240	0.588	0.011	0.007	-0.086	0.367**
Relative water content (%)	0.002	0.351	**-0.463**	-0.049	0.060	-0.325	0.455	-0.032	0.092	0.005	0.025	-0.128	-0.008
Chlorophyll content (SPAD Unit)	-0.014	0.237	-0.038	**-0.599**	0.253	-0.903	0.404	0.303	0.711	0.028	-0.009	-0.011	0.362**
Number of grains per ear	-0.012	-0.196	0.073	0.398	**-0.381**	0.049	0.530	-0.297	-1.108	0.023	-0.009	0.132	-0.799**
Number of tillers per plant	-0.001	0.526	-0.090	-0.322	0.011	**-1.680**	[illegible]	0.182	0.526	0.034	0.034	0.224	0.222*
Flag leaf area (cm^2)	0.004	0.181	-0.143	-0.165	-0.137	-0.890	**1.470**	-0.252	-0.083	-0.009	0.036	0.051	0.064
Relative water loss (%)	0.016	-0.363	-0.030	0.369	-0.231	0.622	0.753	**-0.491**	-0.818	-0.053	0.020	-0.187	-0.392**
Canopy temperature depression (^{0}C)	0.003	-0.396	0.039	0.387	-0.384	0.804	0.111	-0.365	**-1.100**	-0.002	0.023	0.023	-0.857**
Number ofdays to fifty per cent flowering	-0.006	0.044	-0.012	-0.092	-0.047	-0.312	-0.069	0.141	0.012	**0.185**	-0.049	0.197	-0.009
Number of days to maturity	-0.003	0.046	-0.111	[illegible]	0.034	-0.545	0.514	-0.094	-0.248	-0.088	**0.104**	0.189	-0.152
Thousand grain weight (g)	-0.006	0.110	[illegible]	-0.011	0.087	0.646	-0.128	-0.158	0.044	-0.063	-0.034	**-0.582**	-0.197

***,** significantly at 5% and 1% levels, respectively, Residual effect = 0.856**

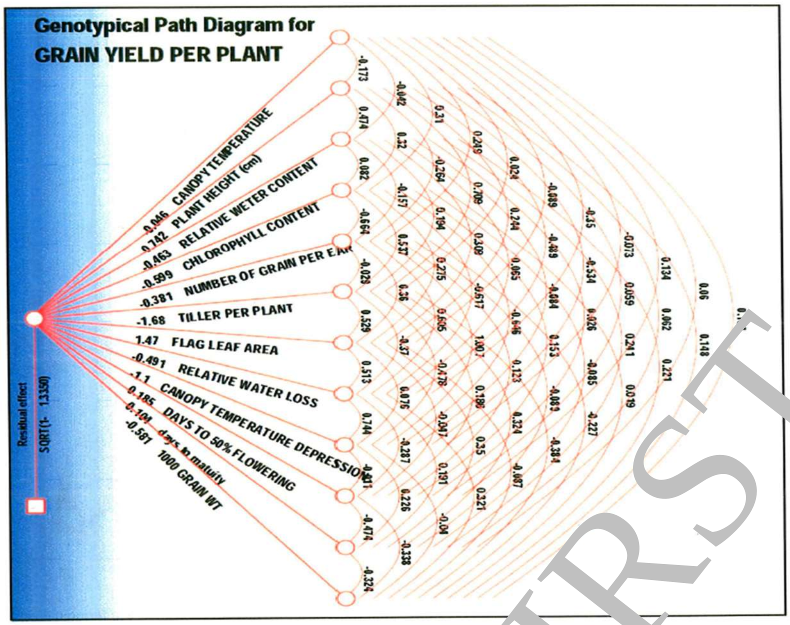

Fig.1: Genotypic Path diagram of yield component effect on grain yield in wheat for thirty-two wheat genotypes

temperature at genotypic level. It indicates that factors such as ability to maintain relative high tissue water status during period of heat stress and an ability to maintain developmental plasticity are partially responsible for heat resistance by reducing canopy temperature. These results were in accordance with Anwar *et al. (*2009) for relative water loss. Characters *viz* chlorophyll content, flag leaf area and days to maturity showed indirect positive effect via relative water loss. Ahmadizadeh *et al.* (2011) also concluded similar results for chlorophyll content. Grain yield correlated positively with tillers per plant, chlorophyll content, and flag leaf but significantly negatively with canopy temperature, relative water loss, and canopy temperature depression at the genotypic level.

Conclusion

The results of the current study demonstrate that various traits such as plant height, chlorophyll content, flag leaf area and canopy temperature depression, can be used to create high yielding wheat varieties under extremely high temperatures. A critical perusal of path coefficient showed that days to fifty percent flowering and number days to maturity had positive direct effect on grain yield at genotypic level, hence selection for such traits would prove beneficial for getting heat tolerant recombinants during selection programme for grain yield under heat stress situation. Future efforts should be focused to fully explore the relationship between physio-morphological traits with yield, this will assist breeders to identify the physio-morphological pathways to sustain sustainable production of wheat against heat stress. Further studies about interrelationships studied by incorporating correlation and path correlation in genetic studies can positively affect the breeding programmes through the incorporation of desirable selection indices that help in successful breeding programme.

Acknowledgement

Authors are grateful to Division of Plant Breeding and Genetics, Faculty of Agriculture. Sher-e-Kashmir University of Agricultural Science and Technology of Jammu, Chatha, for providing seed materials for the current experiment.

Conflict of interest

The authors declare that they have no conflict of interest.

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