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Correlation and Path Analysis in Advance Breeding Lines of Bread Wheat (*Triticum aestivum* L. em. Thall) for Terminal Heat Tolerance

Lalit Kumar[1*], Krishan Kumar[1], O.P. Bishnoi[1], Deepak Kumar[1], Naresh[1], Kavita[1] and Rohit[2]

[1] Department of Genetics and Plant Breeding,
CCS Haryana Agricultural University, Hisar (Haryana), India.
[2]College of Agriculture,
CCS Haryana Agricultural University, Hisar (Haryana), India.

(Corresponding author: Lalit Kumar[*])
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ABSTRACT: Forty bread wheat advance lines were accessed for correlation coefficients and path coefficient analysis, to identify the terminal heat tolerant genotypes. The present investigation was conducted at Wheat and Barley research area, Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar during *rabi* 2019-20 in two sowing conditions (normal and late). Random block design (RBD) design was used with paired row and three replications. Seed yield showed positive and significant correlation with almost all the traits under both conditions except days to maturity, plant height, peduncle length in case of timely sown and days to maturity, grain per spike in case of late sown condition, whereas the results also reveal with path effects by positive direct effect with almost all the traits in both conditions except days to maturity, plant height in timely and only plant height in late sown conditions. Maximum indirect path was recorded for biological yield per plant and harvest index under both the environmental conditions. Based on the correlation coefficients and direct path effects analysis, traits like biological yield per plant, harvest index, 1000- grain weight, NDVI and SPAD value had a strong association with grain yield then other traits; implying sufficient amount of variability present among the genotypes for these traits and selection would be rewarded under heat stress conditions. On the basis of HSI, NW 7049, DBW 14, WH 1021, PBW 825, DBW 304, and PBW 797 lines were determined to be extremely terminal heat tolerant and can be utilized in future recombinant breeding programmes to develop terminal heat tolerant cultivars.

Keywords: advance lines, wheat, NDVI, SPAD, HSI and correlation coefficients.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the most important widely grown cereal crop in the world. It supplements the diets of nearly one third of the world's population by providing nearly half of the protein and more than half of the calories (Yadav *et al.,* 2022). According to 4th estimates production for major crops during 2020-21, area and production under wheat were 34.6 million ha and 109.52 million tonne, respectively (Anonymous, 2021). Wheat possesses a variety of qualities that make it suitable for flour, bread, chapatti, pasta, noodles, cakes and cookies among other cereals. Population growth, particularly in India, makes it impossible to alleviate the problem of hunger in many countries, despite the enormous amount of grain produced. FAO estimates that annual cereal production must increase by nearly one billion tonnes in order to feed the projected population of 9.1 billion people by the end of 2050 (Bishopp and Lynch 2015). There is little likelihood of expanding existing crop-growing areas. Therefore, a substantial increase in crop yield is required to ensure future food security (Parry *et al.,* 2011).

However, grain quality and quantity are affected by biotic and abiotic constraints that limit its productivity. Among abiotic factors, rise in temperature is becoming one of the most significant environmental factors, that impade agriculture crop production worldwide. Since the beginning of century, ambient temperatures have been risen and are expected to continue to rise due to climate change. Such a continuous increase in temperature can cause heat stress, especially during the reproductive and grain filling phases, known as terminal heat stress (Farooq *et al.,* 2011). Heat stress is a function of the magnitude, rate and duration of temperature increase and exposure (Wahid *et al.,* 2007). The IPCC predicts that temperatures will rise by 1.8°C to 5.8°C by the end of this century, and wheat-growing regions will experience terminal heat stress in the near future (Mitra and Bhatia 2008; Dubey *et al.,* 2020).

Wheat is a cold-loving crop, but in India, due to a delay in sowing as a result of late harvesting of rice and cotton, it experiences heat stress at different growth stages. However, heat stress during the reproductive phase is more pronounced than during the vegetative phase due to its direct impact on grain number and dry weight (Wollenweber *et al.,* 2013). The effects of terminal heat stress on reproductive stage leads to reduction in grain filling phase duration, kernel size, biomass, tillers and ultimately its yield. It affects the photosynthetic ability of plants (Wahid *et al.,* 2007), causes metabolic disorders (Farooq *et al.,* 2011), increases the production of oxidative reactive species, which in turn affects pollen tube development, pollen sterility, and pollen mortality (Saini *et al.,* 2010), increases ethylene production, which leads to grain abortion (Hays *et al.,* 2007) and causes oxidative stress (Farooq *et al.,* 2011; Ullah *et al.,* 2022). Thus, to mitigate its large impact on crop production, heat-tolerant varieties must be developed to ensure proper foodsecurity.

Heat tolerance is complex phenomenon that is influenced by environment as well as genotype of crop. Availability of genetic variation for morpho-physiological traits that further having positive association with yield and its contributing traits along with positive direct and indirect effect, offers an opportunity for the breeders to develop genotypes with greater adaptability. For such traits to aid in wheat crop, multiple selection and cross-breeding programmes are required. Keeping in view of above factors, the present study aim was to analyze the correlation and path coefficient analysis for grain yield and its attributing traits and also to evaluate the 40 wheat advance lines for terminal heat stress.

MATERIAL AND METHODS

The present study was conducted at the Wheat and Barley Section, Department of Genetics & Plant Breeding, CCSHAU, Hisar, located at latitude 29.1503° N, longitude 75.7056° E, and altitude 215.2 m above sea level in the semi-tropical region of North-Western India. Forty bread wheat advanced breeding lines were evaluated for 15 morpho-physiological traits in two environments, *i.e.* timely (20th November) and late (20th December) sowing conditions. Experiment was held in randomised block design (RBD) design in three replication with row to row distance 20 cm and plant to plant distance 10 cm for both dates of sowing.

Under both the conditions, observations were recorded on five randomly selected plants for each advance line. Total 15 morpho-physiological traits *viz.,* including days to heading, days to maturity, plant height (cm), number of effective tillers per metre, spike length (cm), peduncle length (cm), number of spikelet per spike, number of grains per spike, 1000 grain weight, biological yield per plant, harvest index (%), grain yield per plant (g), normalised difference vegetation index at the onset of anthesis (NDVI 1), normalised difference vegetation index after 15 days of anthesis (NDVI 2), canopy temperature depression at initiation of anthesis (CTD 1), canopy temperature depression after 15 days of anthesis (CTD 2), SPAD value at initiation of anthesis (SPAD 1) and SPAD value after 15 days of anthesis (SPAD 2) were recorded in natural field conditions.

Statistical analysis. Under both environmental conditions, the mean performance of each trait was measured to determine the significance of differences between genotypes using the method outlined by (Fisher, 1925). Using the variance and covariance components as suggested by Al-Jibouri *et al.* (1958), correlation coefficients between characters were calculated and path coefficients were determined according to Dewey and Lu (1959). The heat susceptibility index (HSI) was computed using the suggested method (Fischer and Maurer, 1978).

$$\text{HSI} = \frac{(1 - \frac{Y}{Y_p})}{(1 - \frac{X}{X_p})}$$

Where,

Y = genotype yield under stress,

Y_p = genotype yield without stress and,

X = average yield over all the genotypes under stress condition,

X_p = average yield over all the genotypes under non-stress condition.

Significantly lowest values of HSI indicates heat tolerance, whereas significantly highest values indicates heat susceptibility of genotype.

RESULTS AND DISCUSSIONS

Correlation coefficients. Grain yield is a multiplex trait that is influenced by a number of yield contributing traits as well as environment (GXE interaction) (Xie, 2015). Analysis of correlation coefficients reveals the degree of association between the yield (dependent variable) and its contributing traits (independent variables); consequently, correlations of various traits would reveal their relative value in terms of yield enhancement. The association between various morpho-physiological traits was determined at the phenotypic level. Separate correlations and path analyses were calculated for morphological and physiological traits in both environments. The phenotypic correlation coefficients were lower than the corresponding genotypic correlation coefficients, which directed that the association was largely due to genetic factors.

Under timely sown conditions, grain yield per plant (Table 1)**,** attained highly significant positive correlations with biological yield per plant, harvest index, number of spikelets per spike, number of grains per spike, number of effective tillers per metre, days to heading, and 1000-grain weight. The results for late-sown conditions (Table 2), were similar with the results of timely-sown conditions, indicating that these traits may be used as selection criteria for screening of heat tolerance in wheat. Mandal *et al.* (2016), Mohanty *et al.* (2016), Sareen *et al.* (2020), and Kumar *et al.* (2022) also reported statistically significant positive correlations between biological yield, harvest index, grains per spike, and 1000-grain weight.

Significant positive correlations were observed between harvest index and 1000-grain weight under both timely and late sown conditions. Under both conditions, there were highly significant correlations between biological yield per plant and number of effective tillers per metre, number of spikelets per spike, number of grains per spike and days to heading. Poudel *et al.* (2021); Al-Ashkar *et al.* (2020) also observed identical outcomes for thousand grain weight and number of grains per spike.

Under timely sown conditions, 1000-grain weight revealed significant correlations with days to heading, days to maturity, and number of effective tillers per metre which was in accordance with Barman *et al.* (2020); Ojha *et al.* (2018). Under late sown conditions, only plant height revealed strong correlations. Significant correlations were existed between peduncle length, plant height, and spike length. A similar pattern was also observed for late-sown conditions, except for the number of effective tillers per metre which showed non-significant correlations with 1000-grain weight. Sherawat *et al.* (2021); Kumar *et al.* (2022) also identified significant correlations between peduncle length, plant height, and spike length in their studies.

The correlation coefficients of physiological traits for both timely and late sown conditions is give in Table 3 and 4, respectively. All physiological traits exhibited significant correlations with grain yield per plant under and late sown conditions, except CTD 2 which exhibited non-significant correlations under late sown conditions. The above results are in accordance with the studies of Mondal *et al.* (2013); Sherawat *et al*. (2021). Therefore, it can be inferred from the correlation studies that traits such as grain yield, biological yield, harvest index, 1000-grain weight, peduncle length, and all physiological traits besides CTD can be used as selection criteria for the screening of wheat lines. As a result, to improve grain yield, associated components should be dealt simultaneously.

Path analysis. Path coefficient analysis was used to partition the computed genotypic correlation coefficients of different plant attributes into direct and indirect effects. The grain yield per plant was considered the dependent factor (effect), whereas other characteristics were considered independent factors (causes).

Morphological traits. Under timely sown conditions, (Table 5), biological yield per plant had the highest significant direct effect on grain yield per plant (0.6981), followed by harvest index (0.6273), 1000 grain weight (0.1036), peduncle length (0.0418), spike length (0.0361), days to maturity (0.0329), number of spikelets per spike (0.0188), number of grains per spike (0.0143) and number of effective tillers per metre (0.0028). Days to heading had the greatest negative direct effect (-0.0741). Mandal *et al.* (2016); Chairi *et al.* (2020) also reported identical findings regarding spike length and spikelet number in their studies. Baye *et al.* (2020); Suresh *et al.* (2018) identified a direct relationship between peduncle length and 1000-grain weight and grain yield. The estimates for late sown conditions, (Table 6), revealed similar outcomes as in normal conditions for nearly all traits, with an exception of days to heading (0.0116), which had a positive direct effect instead of a negative one. These findings are comparable to those of Ayer *et al*. (2017); Vaghela *et al*. (2021) studies. The presence of a positive direct effect of various traits indicates their direct contribution to grain yield and the absence of a significant difference between the two conditions indicates that these traits are stable and may be utilized for screening purposes.

Under both conditions, biological yield per plant, 1000-grain weight, and harvest index had a stronger relationship with grain yield and a greater direct effect on grain yield. Therefore, we can use these three traits as selection criteria under the condition of terminal heat stress.

Physiological traits. Under of timely sown conditions (Table 7), the path coefficient analysis revealed that CTD-1 (0.3647) had the greatest direct effect on grain yield per plant, followed by SPAD-1 (0.1712), NDVI-2 (0.1671), SPAD-2 (0.1146), NDVI-1 (0.0413), and CTD-2. (0.0127), whereas SPAD-1 (0.3130) had the greatest direct effect on grain yield per plant under late sown conditions (Table 8), followed by CTD-1 (0.1380), CTD-2 (0.1110), NDVI-2 (0.1050), NDVI-1 (0.0720), and SPAD-2. (0.0610). Joshi *et al.* (2021); Sherawat *et al*. (2021) also reported similar outcomes under two conditions in their experiments. All physiological parameters exhibited a direct positive effect on grain yield under both conditions, signifying the importance of these traits in grain yield enhancement. Lower values of residual effects for grain yield and its attributing traits under both normal (0.0041) and late sown (0.0103) conditions indicated that the traits under investigation covered majority of the variability present in wheat lines.

Heat Susceptibility Index (HSI). The main aim of the present study was to identify the terminal heat tolerant lines. It is not reliable to estimate the grain yield and component traits alone for heat tolerance. Various screening methods have been formulated by various researchers, but heat susceptibility index (Fischer and Maurer, 1978) has proved to be effective parameters for screening wheat genotypes for heat tolerance. The lower value (<0.50) of heat susceptibility index (HSI) was observed for NW 7049 (0.31), DBW 14 (0.37), WH 1021 (0.37), PBW 825 (0.44), DBW 304 (0.47) and PBW 797 (0.48). These six advance lines can be used in breeding programmes to develop the terminal heat tolerant wheat cultivars for late sown conditions. The HSI scale used in differentiation of tolerant and susceptible was from the study of Kumar *et al.* (2018).

Table 1: Phenotypic correlation coefficients for 12 different morphological traits in wheat advance lines under timely sown conditions.

Traits	DH	DM	PH	ET/m	SL	PL	SL/S	G/S	TGW	BY/P	HI	GY/P
DH	1.00	0.085	0.014	0.197*	0.176	0.102	0.150	0.029	0.227*	0.215*	0.045	0.180*
DM		1.00	0.062	0.104	-0.086	-0.120	0.100	-0.032	0.189*	0.008	-0.005	0.004
PH			1.00	0.249**	0.219*	0.299**	0.192*	0.203*	0.005	0.182*	-0.041	0.081
ET/m				1.00	-0.035	0.031	0.219*	0.159	0.192*	0.354**	0.193*	0.397**
SL					1.00	0.228*	-0.003	0.112	0.080	0.213*	0.113	0.236**
PL						1.00	-0.077	0.115	0.071	0.113	0.107	0.154
SL/S							1.00	0.182*	0.003	0.316**	0.091	0.287**
G/S								1.00	0.175	0.247**	0.285**	0.383**
TGW									1.00	0.140	0.468**	0.453**
BY/P										1.00	-0.090	0.635**
HI											1.00	0.706**
GY/P												1.00

*, **significant at 5 % and 1% level of significance, respectively

(**DH**: Days to heading, **DM**: Days to maturity, **PH**: Plant height (cm), **ET/m**: Number of effective tiller per meter, **SL**: Spike length (cm), **PL**: Peduncle length (cm), **SL/S**: Number of spikelets per spike, **G/S**: Grains per spike, **TGW**: 1000-grain weight (g), **BY/P**: Biological yield per plant (g), **GY/P**: Grain yield per plant (g), **HI**: Harvest index (%)).

Table 2: Phenotypic correlation coefficients for 12 different morphological traits in wheat advance lines under late sown conditions.

Traits	DH	DM	PH	ET/m	SL	PL	SL/S	G/S	TGW	BY/P	HI	GY/P
DH	1.00	0.095	0.122	0.303**	0.026	-0.044	0.083	0.140	-0.127	0.199*	-0.359**	-0.229*
DM		1.00	0.205*	0.141	0.012	-0.128	0.179	-0.290**	0.027	0.050	-0.075	-0.011
PH			1.00	0.313**	0.338**	0.262**	0.391**	0.059	0.313**	0.154	0.219*	0.423**
ET/m				1.00	0.224*	0.296**	0.306**	-0.137	-0.056	0.310**	-0.104	0.188*
SL					1.00	0.274**	0.322**	-0.046	0.098	0.106	0.159	0.292**
PL						1.00	0.192*	-0.002	0.147	0.125	0.175	0.342**
SL/S							1.00	0.034	0.177	0.236**	0.216*	0.478**
G/S								1.00	0.010	0.078	0.069	0.159
TGW									1.00	0.106	0.268**	0.416**
BY/P										1.00	-0.575**	0.305**
HI											1.00	0.588**
GY/P												1.00

*, **significant at 5 % and 1% level of significance, respectively

(**DH**: Days to heading, **DM**: Days to maturity, **PH**: Plant height (cm), **ET/m**: Number of effective tiller per meter, **SL**: Spike length (cm), **PL**: Peduncle length (cm), **SL/S**: Number of spikelets per spike, **G/S**: Grains per spike, **TGW**: 1000-grain weight (g), **BY/P**: Biological yield per plant (g), **GY/P**: Grain yield per plant (g), **HI**: Harvest index (%)).

Table 3: Phenotypic correlation coefficients for 3 different physiological traits in wheat advance lines under timely sown conditions.

Physiological Traits	NDVI-1	NDVI-2	CTD-1	CTD-2	SPAD-1	SPAD-2	GY/P
NDVI-1	1.00	0.547**	0.131	0.235**	0.230*	0.125	0.218*
NDVI-2		1.00	0.187*	0.144	0.060	0.085	0.220*
CTD-1			1.00	0.565**	0.137	0.120	0.260**
CTD-2				1.00	0.191*	0.044	0.325**
SPAD-1					1.00	0.470**	0.264**
SPAD-2						1.00	0.264**
GY/P							1.00

*, **significant at 5 % and 1% level of significance, respectively

(**NDVI 1**: Normalized difference vegetation index at initiation of anthesis, **NDVI 2**: Normalized difference vegetation index after 15 days of anthesis, **CTD 1**: Canopy temperature depression at initiation of anthesis, **CTD 2**: Canopy temperature depression after 15 days of anthesis, **SPAD1**: Soil plant analysis development at initiation of anthesis, **SPAD 2**: Soil plant analysis development after 15 days of anthesis, **GY/P**: Grain yield per plant (g)).

Table 4: Phenotypic correlation coefficients for 3 different physiological traits in wheat advance lines under late sown conditions.

Physiological traits	NDVI 1	NDVI 2	CTD 1	CTD 2	SPAD 1	SPAD 2	GY/P
NDVI 1	1.00	0.330**	0.172	0.156	0.333**	0.170	0.265**
NDVI 2		1.00	0.302**	0.383**	0.296**	0.173	0.276**
CTD 1			1.00	0.478**	0.129	0.024	0.250**
CTD 2				1.00	-0.105	-0.116	0.137
SPAD 1					1.00	0.821**	0.331**
SPAD 2						1.00	0.265**
GY/P							1.00

*, **significant at 5 % and 1% level of significance, respectively

(**NDVI 1**: Normalized difference vegetation index at initiation of anthesis, **NDVI 2**: Normalized difference vegetation index after 15 days of anthesis, **CTD 1**: Canopy temperature depression at initiation of anthesis, **CTD 2**: Canopy temperature depression after 15 days of anthesis, **SPAD 1**: Soil plant analysis development at initiation of anthesis, **SPAD 2**: Soil plant analysis development after 15 days of anthesis, **GY/P**: Grain yield per plant (g)).

Table 5: Direct (diagonal values) and indirect effects of different morphological traits on grain yield in wheat advance lines under timely sownconditions.

	DH	DM	PH	ET/m	SL	PL	SL/S	G/S	TGW	BY/P	HI	GY/P
DH	**-0.0178**	0.0043	-0.0054	0.0007	0.0079	0.0045	0.0041	0.0024	0.0017	0.1908	0.0570	0.250**
DM	-0.0023	**0.0329**	-0.0084	0.0006	-0.0038	-0.0056	0.0051	-0.0004	0.0010	0.0445	0.0692	0.133^{NS}
PH	-0.0013	0.0038	**-0.0741**	0.0009	0.0125	0.0212	0.0046	0.0026	0.0001	0.1237	-0.1226	-0.029^{NS}
ET/m	-0.0048	0.0076	-0.0244	**0.0028**	-0.0024	0.0058	0.0104	0.0003	0.0007	0.2839	0.0504	0.330**
SL	-0.0039	-0.0034	-0.0257	-0.0002	**0.0361**	0.0145	0.0005	0.0025	0.0004	0.2067	0.0905	0.318**
PL	-0.0019	-0.0044	-0.0375	0.0004	0.0126	**0.0418**	-0.0027	0.0022	0.0002	0.1261	0.1250	0.262**
SL/S	-0.0039	0.0089	-0.0180	0.0015	0.0009	-0.0061	**0.0188**	0.0037	0.0003	0.2960	0.0996	0.402**
G/S	-0.0030	-0.0010	-0.0134	0.0001	0.0063	0.0064	0.0048	**0.0143**	0.0007	0.2646	0.1202	0.400**
BY/P	-0.0083	0.0095	-0.0016	0.0005	0.0042	0.0021	0.0014	0.0029	**0.1036**	0.1415	0.3996	0.555**
TGW	-0.0049	0.0021	-0.0131	0.0011	0.0107	0.0076	0.0080	0.0054	0.0007	**0.6981**	0.0299	0.746**
HI	-0.0016	0.0036	0.0145	0.0002	0.0052	0.0083	0.0030	0.0027	0.0023	0.0333	**0.6273**	0.699**

Residual factor = 0.0041

(**DH**: Days to heading, **DM**: Days to maturity, **PH**: Plant height (cm), **ET/m**: Number of effective tiller per meter, **SL**: Spike length (cm), **PL**: Peduncle length (cm), **SL/S**: Number of spikelets per spike, **G/S**: Grains per spike, **TGW**: 1000-grain weight (g), **BY/P**: Biological yield per plant (g), **GY/P**: Grain yield per plant (g), **HI**: Harvest index (%)).

Table 6: Direct (diagonal values) and indirect effects of different morphological traits on grain yield in wheat advance lines under late conditions.

Traits	DH	DM	PH	ET/m	SL	PL	SL/S	G/S	TGW	BY/P	HI	GY/P
DH	**0.0116**	0.0080	-0.0195	0.0024	0.0001	-0.0004	0.0002	0.0006	-0.0327	0.2507	-0.5054	-0.2840**
DM	0.0015	**0.0638**	-0.0324	0.0014	0.0001	-0.0010	0.0005	-0.0020	0.0014	0.0529	-0.1122	-0.0260^{NS}
PH	0.0019	0.0177	**-0.1170**	0.0030	0.0016	0.0046	0.0011	0.0002	0.0647	0.3406	0.2368	0.5550**
ET/m	0.0048	0.0154	-0.0613	**0.0057**	0.0011	0.0050	0.0010	-0.0017	-0.0065	0.4520	-0.1675	0.2480**
SL	0.0004	0.0002	-0.0474	0.0016	**0.0039**	0.0047	0.0009	-0.0004	0.0170	0.1772	0.2546	0.4130**
PL	-0.0004	-0.0060	-0.0493	0.0027	0.0017	**0.0108**	0.0005	-0.0006	0.0203	0.2771	0.1582	0.4150**
SL/S	0.0014	0.0176	-0.0682	0.0032	0.0020	0.0027	**0.0018**	-0.0003	0.0253	0.4292	0.0852	0.5000**
G/S	0.0011	-0.0199	-0.0043	-0.0015	-0.0002	-0.0010	-0.0001	**0.0065**	0.0039	0.2480	-0.0460	0.1870*
BY/P	-0.0030	0.0007	-0.0592	-0.0003	0.0005	0.0017	0.0004	0.0002	**0.1278**	-0.0046	0.4000	0.4640**
TGW	0.0031	0.0036	-0.0419	0.0027	0.0007	0.0032	0.0008	0.0017	-0.0006	**0.9508**	-0.4124	0.5120**
HI	-0.0061	-0.0075	-0.0291	-0.0010	0.0011	0.0018	0.0002	-0.0003	0.0538	-0.4122	**0.9502**	0.5520**

Residual factor = 0.0103

(**DH**: Days to heading, **DM**: Days to maturity, **PH**: Plant height (cm), **ET/m**: Number of effective tillers per meter, **SL**: Spike length (cm), **PL**: Peduncle length (cm), **SL/S**: Number of spikeletsper spike, **G/S**: Grains per spike, **TGW**: 1000-grain weight (g), **BY/P**: Biological yield per plant (g), **GY/P**: Grain yield per plant (g), **HI**: Harvest index (%)).

Table 7: Direct (diagonal values) and indirect effects of different physiological traits on grain yield in wheat advance lines under timely sownconditions.

Characters	NDVI 1	NDVI 2	CTD 1	CTD 2	SPAD 1	SPAD 2	GY/P
NDVI 1	**0.0413**	0.1014	0.0745	-0.0064	0.0438	0.0069	0.2620**
NDVI 2	0.0251	**0.1671**	0.0860	-0.0032	0.0049	0.0045	0.2840**
CTD 1	0.0084	0.0394	**0.3647**	-0.0090	0.0381	0.0174	0.4590**
CTD 2	0.0208	0.0419	0.2568	**0.0127**	0.0575	-0.0010	0.3630**
SPAD 1	0.0106	0.0047	0.0811	-0.0043	**0.1712**	0.0407	0.3040**
SPAD 2	0.0025	0.0066	0.0554	0.0001	0.0608	**0.1146**	0.2400**

(**NDVI 1**: Normalized difference vegetation index at initiation of anthesis, **NDVI 2**: Normalized difference vegetation index after 15 days of anthesis, **CTD 1**: Canopy temperature depression at initiation of anthesis, **CTD 2**: Canopy temperature depression after 15 days of anthesis, **SPAD 1**: Soil plant analysis development at initiation of anthesis, **SPAD 2**: Soil plant analysis development after 15 days of anthesis, **GY/P**: Grain yield per plant (g))

Table 8: Direct (diagonal values) and indirect effects of different physiological traits on grain yield in wheat advance lines under late sownconditions.

Characters	NDVI 1	NDVI 2	CTD 1	CTD 2	SPAD 1	SPAD 2	GY/P
NDVI 1	**0.0720**	0.0430	0.0290	0.0210	0.1530	0.0160	0.3330**
NDVI 2	0.0300	**0.1050**	0.0470	0.0460	0.1170	0.0110	0.3550**
CTD 1	0.0150	0.0360	**0.1380**	0.0550	0.0480	0.0030	0.2940**
CTD 2	0.0130	0.0430	0.0690	**0.1110**	-0.0390	-0.0080	0.1880*
SPAD 1	0.0350	0.0390	0.0210	-0.0140	**0.3130**	0.0520	0.4460**
SPAD 2	0.0190	0.0190	0.0060	-0.0150	0.2640	**0.0610**	0.3540**

(**NDVI 1**: Normalized difference vegetation index at initiation of anthesis, **NDVI 2**: Normalized difference vegetation index after 15 days of anthesis, **CTD 1**: Canopy temperature depression at initiation of anthesis, **CTD 2**: Canopy temperature depression after 15 days of anthesis, **SPAD 1**: Soil plant analysis development at initiation of anthesis, **SPAD 2**: Soil plant analysis development after 15 days of anthesis, **GY/P**: Grain yield per plant (g))

CONCLUSION AND FUTURE SCOPE

In the present investigation, based on the study of character association and path analysis, the traits like biological yield per plant, harvest index, 1000-grain weight, NDVI, and SPAD value may be taken as selection criteria for both morpho-physiological parameters for screening of genotypes for heat tolerance due to their strong association and positive direct effect on grain yield under both the conditions;

therefore, direct selection for these traits will be effective for yield improvement. On the basis of the heat susceptibility index (HSI) for all genotypes, the lines *viz.*, WH1021, NW7049, DBW14, BRW 3806, PBW797, PBW 825, and DBW 304 were determined to be highly tolerant for terminal heat stress and may be significantly utilized in future crop improvement programmes.

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