Full Research Article

Genetic Variability, Correlation and Path Analysis of Bread Wheat (*Triticum aestivum* L.) Genotypes under Terminal Heat Stress

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Abstract

Present study investigated the genetic variability, correlation and path analysis on various yield attributing traits of forty nine bread wheat (*Triticum aestivum* L.) genotypes grown at Kalyani, Nadia, West Bengal during *rabi* season for two consecutive years 2013–2014 and 2014–2015 enduring with terminal heat stress. Wide spectrum variability was revealed for all the characters studied which could provide scope for improvement through selection. High Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV), heritability, Genetic advance (GA), GA (%) of mean was observed in the characters viz., proline content, no. of tillers plant⁻¹, no. of spikes plant⁻¹, no. of grains spike⁻¹ and yield plant⁻¹ under late heat stress condition. The genotypes viz. GW 2011-403, WSM 135, GW 2008-153, RAJ 4358, RAJ 4362, J-07-47 & UP 2783 were found to be high yielders may exploit towards heat tolerance. Yield plant⁻¹ was found to have significant positive association with plant height, no. of tillers plant⁻¹, no. of spikes plant⁻¹, spike length, no. of spikelets spike⁻¹, no. of florets spike⁻¹, no. of grains spike⁻¹, floret fertility and grain weight spike⁻¹ at both genotypic and phenotypic levels; while a significant negative correlation was observed with chlorophyll-a and total chlorophyll content at both the levels and chlorophyll-b at genotypic level only. Considering path coefficient analysis, no. of tillers plant⁻¹, spike length, no. of florets spike⁻¹ and floret fertility were mentioned as selection criteria under late heat stress.

1. Introduction

Wheat is the second most important food crop showing greater genetic variability and diversity among the different genotypes in every corner of the world. India is the 2nd largest producer of wheat followed by China contributing 13.53% of area to total area of world under wheat cultivation. The wheat production and productivity of India was 93.48 mt and 3.02 t ha⁻¹ respectively in 2013–2014. Climate change is projecting perilous effects on agricultural production all over world. In India, wheat production is to be reduced by about 6% and 18% by 2020 in timely sown irrigated and late sown wheat respectively as reported by Shetty et al., 2013. The enhancement of surface temperature and night temperature clearly demarcated the impact of greenhouse gases. Almost all late sown area is in the eastern Gangetic plains, most of which occurs in the North Eastern Plain Zone (NEPZ) of India, suffers from heat stress at reproductive stage. Wheat (*Triticum aestivum* L.) is a temperate cereal with an optimum temperature regime of 15–18 °C during the grain filling stage (Lobell et al., 2011) but daily high temperature of 25–30 °C or greater is common across many regions where wheat is grown

(Mohammadi, 2012).

Wheat is cultivated in West Bengal in the month of November and December using residual fertility of soil under typical agro-climatic condition of state. The optimum time for growing of wheat is middle of November. In late sown condition (mid December), wheat is often affected due to sudden rise in temperature resulting in the initiation of reproductive phase even before completion of the required period for vegetative growth of the crop. This reduces the tiller no., spike length and grain size subsequently causing substantial loss in yield. Our research dealt with comprehensive study on genetic variability of different morphological, physiological traits and their association with yield as well as direct and indirect effects under terminal heat stress.

2. Materials and Methods

Forty nine genotypes of bread wheat (*Triticum aestivum* L.) were collected from Indian Institute of Wheat and Barley Research (IIWBR), Karnal through All India Coordinated Wheat and Barley Improvement Project (AICW and BIP). The experiment was conducted for 2 consecutive years viz.

2013–14 and 2014–15 at AB block, Kalyani, Nadia, West Bengal, India following randomized block design with 2 replications. The genotypes were AKAW 4498, AKAW 4702, WSM 135, DBW 74, DBW 113, DBW 118, DBW 125, WSM 131, DL 1058, GW 2008–153, GW 2008–161, GW 2010–321, GW 2011–398, GW 2011–399, GW 2011–403, GW 2012–474, GW 2012–475, RAJ 4360, GW 2011–404, GW 2012–471, GW 2012–472, GW 2012–473, VW 964, GW 2012–476, GW 2012–477, NIAW 2302, NIAW 2415, NIAW 2421, NWL-9–3, NWL-9–5, RAJ 4274, RAJ 4314, VL 946, J-07–47, RAJ 4318, RAJ 4358, RAJ 4359, RAJ 4361, RAJ 4362, RWP 2009–05, RWP 2011–15, RWP 2011–17, RWP 2011–18, UP 2783 and 5 checks viz., DBW 14^o, RAJ 3765^o, HALNA^o, HD 2285^o, Sonalika. Sowing was done on 15th December and 16th December of 2013 and 2014 respectively. Each plot consisted of two rows of 1.5 m length with a spacing of 25×50 cm². The average weekly temperature of 2013–14 and 2014–15 were recorded and presented in graph 1. All the recommended package of practices for wheat was followed to raise a healthy crop. Data were recorded on five randomly and competitive plants of each genotype. Genetic variability, correlation and path coefficient analysis were carried out over pooled data estimated. The various characters studied were days to maturity, days to heading, days to flowering, chlorophyll-a content (mg g⁻¹), chlorophyll-b content (mg g⁻¹), total chlorophyll content (mg g⁻¹), grain proline content (μg g⁻¹), no. of tillers plant⁻¹, no. of spikes plant⁻¹, spike length (cm), no. of spikelets spike⁻¹, no. of grains spike⁻¹, floret fertility (%), grain weight spike⁻¹ (g), test weight (g) and yield plant⁻¹ (g).

3. Results and Discussion

3.1. Genetic parameters for yield and its attributing characters

The genetic parameters of 49 genotypes of wheat estimated on pooled data are presented in Table 1. Genotypic and phenotypic variance were spotted to have higher value for characters such as plant height, flag leaf area, proline content, no. of florets spike⁻¹, no. of grains spike⁻¹ and floret fertility implying greater variation among the genotypes for these traits. The character flag leaf area and floret fertility were greatly influenced by environment having higher environmental variance. The magnitude of Phenotypic Coefficient of Variation (PCV) was higher than the corresponding Genotypic Coefficient of Variation (GCV) values for the characters viz., flag leaf area, chlorophyll-a, chlorophyll-b, total chlorophyll and spike length indicating the influence of environment on the expression of these characters supporting the work of Singh et al. (2013). A closer PCV and GCV was observed for the characters viz., days to maturity, days to heading, days to flowering, plant height, proline content, no. of tillers plant⁻¹, no. of spikes plant⁻¹, no. of spikelets spike⁻¹, no. of florets spike⁻¹, no. of grains spike⁻¹, floret fertility, grain weight spike⁻¹, test weight and yield plant⁻¹ showing little environment effect on the

expression of these characters. Therefore, there is a large scope of genetic improvement of those traits under terminal heat stress. High value of GCV and PCV was recorded in chlorophyll-b, proline content, no. of tillers plant⁻¹, no. of spikes plant⁻¹, yield plant⁻¹. There was little variability and scope for selection in the materials for days to maturity, days to 50% flowering and days to heading, having lower GCV and PCV. This result was in agreement with Mishra and Marker (2013). Plant height, flag leaf area, proline content, no. of florets spike⁻¹, no. of grains spike⁻¹, floret fertility and test weight indicated high heritability coupled with high genetic advance. Chlorophyll-a, chlorophyll-b, total chlorophyll content, spike length, no. of spikelets spike⁻¹ and grain weight spike⁻¹ showed moderate to high heritability combined with low genetic advance. The characters chlorophyll-a, chlorophyll-b, total chlorophyll content showed moderate to high heritability with high Genetic Advance (GA) per cent of mean. These traits are controlled by both additive and non-additive genes. Population improvement and cyclic selection may be followed for these characters. Proline content, no. of tillers plant⁻¹, no. of spikes plant⁻¹, grain weight spike⁻¹ and yield plant⁻¹ indicated high heritability accompanied with greater GA % of mean. These characters are controlled by additive genes and direct selection for these characters may be effective under terminal heat stress. As wheat is a self-pollinated crop pureline selection, mass selection, progeny selection or hybridization followed by next generation selection is effective for genetic improvement. High PCV, GCV, heritability, GA, GA % of mean was observed for the characters viz., proline content, no. of tillers plant⁻¹, no. of spikes plant⁻¹, no. of grains spike⁻¹ and yield plant⁻¹ under late heat stress condition in 49 genotypes of wheat. It implies that, these characters showed predominance of additive gene action which favours stabilizing selection for accumulation of alleles. Similar result was obtained by Mishra and Marker (2013) for relative injury, chlorophyll content, grains spike⁻¹, tillers plant⁻¹, plant height and spike length. Riaz-ud-din et al. (2010) also reported for grain filling duration, grains spike⁻¹, 1000-grain weight and grain yield plot⁻¹ under normal and late planting conditions. Yield plant⁻¹ was found to be highest in GW 2011–403 (18.063 gm) followed by WSM 135, GW 2008–153, RAJ 4358, RAJ 4362, J-07–47 & UP 2783. As these genotypes were noted to have greater yield plant⁻¹ under terminal heat stress that may be reflected to higher heat tolerance. This statement was in accordance with Meena and Verma (2014) who testified that, high grain yield of a genotype under late sown condition indicated the presence of gene for heat tolerance.

3.2. Character association

Selection of a character may lead to simultaneous improvement in associated characters from which understanding the inter-allelic relationship among different characters is essential to make any programme on improvement of character following

Table 1: Genetic parameters for yield and its attributing characters of bread wheat estimated on pooled data

Characters	A	B	C	D	E	F	G	H	I	J	K	L
DM	100.367	90.5–105.5	0.838	7.376	8.079	0.703	0.835	2.706	2.832	91.31	5.346	5.326
DH	60.724	51.5–71.5	0.832	18.405	19.094	0.689	1.37	7.065	7.196	96.373	8.676	14.287
Days to flowering	66.633	56.5–78.5	0.923	22.590	23.447	0.857	1.386	7.133	7.267	96.364	9.612	14.425
Plant height (cm)	91.004	70.3–107.69	1.370	53.774	55.645	1.871	1.506	8.058	8.197	96.364	14.849	16.317
Flag leaf area (cm ²)	28.707	17.63–39.505	2.061	32.618	36.867	4.249	7.18	19.895	21.151	88.477	11.067	38.551
Chlorophyll a (mg g ⁻¹)	0.248	0.085–0.377	0.026	0.004	0.005	0.001	10.367	26.193	28.17	86.455	0.124	50.17
Chlorophyll b (mg g ⁻¹)	0.131	0.014–0.287	0.037	0.004	0.005	0.001	28.28	47.562	55.334	73.88	0.11	84.214
Total chlorophyll (mg g ⁻¹)	0.379	0.107–0.654	0.051	0.015	0.018	0.003	13.463	32.249	34.947	85.159	0.232	61.306
Proline (μ M g ⁻¹)	7.659	0.95–34.265	0.462	34.745	34.959	0.213	6.027	76.962	77.198	99.39	12.106	158.059
No. of tillers plant ⁻¹	8.635	2–14.92	0.325	9.029	9.135	0.106	3.764	34.799	35.002	98.844	6.154	71.27
No. of spikes plant ⁻¹	7.618	1–14.655	0.312	9.601	9.698	0.097	4.091	40.675	40.88	98.998	6.351	83.369
Spike length (cm)	9.711	7.905–12.635	0.582	0.927	1.266	0.339	5.996	9.913	11.585	73.207	1.697	17.471
No. of spikelet spike ⁻¹	15.232	11.839–20.667	0.816	2.504	3.169	0.665	5.356	10.388	11.687	79.005	2.897	19.021
No. of florets spike ⁻¹	46.301	35.735–65.99	1.210	34.861	36.325	1.464	2.613	12.752	13.017	95.964	11.914	25.733
No. of grains spike ⁻¹	37.79	25.979–56.95	0.428	42.199	42.386	0.187	1.134	17.19	17.228	99.564	13.353	35.334
Floret fertility (%)	81.449	55.193–92.511	2.151	48.757	53.389	4.632	2.641	8.573	8.971	91.332	13.747	16.878
Grain weight spike ⁻¹ (g)	1.448	0.692–2.939	0.073	0.161	0.166	0.005	5.066	27.692	28.151	96.762	0.813	56.114
Test weight (g)	37.763	29.082–51.13	0.338	26.586	26.703	0.117	0.894	13.654	13.684	99.57	10.599	28.068
Yield plant ⁻¹ (g)	9.494	3.957–18.063	0.690	12.890	13.365	0.475	7.264	37.816	38.507	96.442	7.263	76.503

A: Mean; B: Range; C: Standard error deviation; D: Genotypic variance; E: Phenotypic variance; F: Environmental variance; G: CV, H: GCV; I: PCV, J: h² (BS) %; K: GA; L: GA (%) Mean; DM: Days to maturity; DH: Days to heading

appropriate method of plant breeding. The genotypic and phenotypic correlation coefficients were estimated from pooled data and being presented in Table 2. The genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients in most of the cases which indicated that the association was largely due to genetic factors.

Days to flowering attained a non-significant negative

correlation with yield plant⁻¹ which was in accordance with Mohammadi et al. (2012); Zafarnaderi et al. (2013). Plant height showed significant positive correlation with flag leaf area, spike length, no. of florets spike⁻¹, no. of grains spike⁻¹, floret fertility, grain weight spike⁻¹ and yield plant⁻¹ at genotypic as well as phenotypic level. Chlorophyll content showed strong significant negative association with no. of tillers plant⁻¹, no. of

Table 2: Genotypic (G) and Phenotypic (P) correlation among yield and its attributing characters estimated on pooled data

		DH	DF	PH	FLA	CHL a	CHL b	TOT CHL	PRL	TLRS	SPKS	SP LEN	SKLTS
DM	G	0.226*	0.201*	0.046	-0.207*	-0.229*	-0.283**	-0.266**	0.162	0.009	0.001	-0.052	-0.023
	P	0.220*	0.183	0.033	-0.189	-0.193	-0.248*	-0.238*	0.15	0.01	0.008	-0.021	-0.014
DH	G		0.981**	0.021	0.259**	-0.244*	-0.251*	-0.258*	-0.177	-0.07	-0.095	0.146	0.17
	P		0.961**	0.015	0.238*	-0.233*	-0.235*	-0.251*	-0.174	-0.071	-0.091	0.123	0.134
DF	G			0.011	0.266**	-0.193	-0.208*	-0.208*	-0.152	-0.062	-0.07	0.138	0.128
	P			0.027	0.239*	-0.182	-0.162	-0.185	-0.147	-0.066	-0.072	0.143	0.123
PH	G				0.225*	-0.157	0.022	-0.072	-0.275**	0.120	0.152	0.329**	0.184
	P				0.214*	-0.135	0.019	-0.06	-0.274**	0.119	0.149	0.276**	0.158
FLA	G					-0.18	-0.177	-0.186	-0.097	-0.021	-0.001	0.318**	0.277**
	P					-0.148	-0.131	-0.15	-0.096	-0.02	-0.005	0.238*	0.209*
CHL a	G						0.847**	0.963**	0.002	-0.405**	-0.378**	-0.036	-0.158
	P						0.733**	0.929**	0.005	-0.369**	-0.342**	-0.015	-0.106
CHL b	G							0.959**	0.064	-0.269**	-0.260**	0.084	-0.057
	P							0.933**	0.066	-0.232*	-0.225*	0.095	-0.044
TOT	G								0.034	-0.352**	-0.334**	0.023	-0.113
CHL	P								0.038	-0.322**	-0.303**	0.044	-0.08
PRL	G									-0.194	-0.197	-0.088	-0.213*
	P									-0.194	-0.195	-0.075	-0.188
TLRS	G										0.987**	-0.051	-0.071
	P										0.981**	-0.054	-0.077
SPKS	G											-0.045	-0.085
	P											-0.041	-0.084
SP	G												0.813**
LEN	P												0.664**
SKLTS	G												
	P												
FLTS	G												
	P												
GRNS	G												
	P												
FERT	G												
	P												
GRN	G												
WT	P												
TS WT	G												
	P												

Continue...

		FLTS	GRNS	FERT	GRN WT	TS WT	YLD
DM	G	-0.085	-0.097	-0.052	-0.03	0.035	0.046
	P	-0.064	-0.09	-0.067	-0.037	0.03	0.038
DH	G	0.149	-0.039	-0.312**	-0.322**	-0.361**	-0.152
	P	0.141	-0.039	-0.288**	-0.312**	-0.357**	-0.146
DF	G	0.098	-0.089	-0.334**	-0.308**	-0.329**	-0.121
	P	0.09	-0.086	-0.306**	-0.294**	-0.322**	-0.115
PH	G	0.350**	0.420**	0.334**	0.352**	0.029	0.279**
	P	0.346**	0.414**	0.304**	0.331**	0.025	0.262**
FLA	G	0.442**	0.316**	-0.045	0.199*	-0.042	0.189
	P	0.399**	0.296**	-0.029	0.17	-0.04	0.176
CHL a	G	-0.04	-0.169	-0.292**	0.046	0.187	-0.409**
	P	-0.049	-0.161	-0.249*	0.039	0.172	-0.371**
CHL b	G	0.064	-0.017	-0.134	0.205*	0.254*	-0.268**
	P	0.053	-0.02	-0.117	0.177	0.226*	-0.19
TOT	G	0.011	-0.099	-0.224*	0.129	0.229*	-0.354**
CHL	P	0.003	-0.096	-0.195	0.117	0.214*	-0.300**
PRL	G	-0.156	-0.062	0.109	0.057	0.112	-0.106
	P	-0.155	-0.062	0.107	0.059	0.112	-0.104
TLRS	G	-0.161	0.1	0.461**	0.047	-0.017	0.669**
	P	-0.158	0.098	0.437**	0.046	-0.016	0.660**
SPKS	G	-0.156	0.1	0.451**	0.053	-0.012	0.664**
	P	-0.154	0.1	0.434**	0.051	-0.013	0.651**
SP	G	0.759**	0.642**	0.128	0.574**	0.311**	0.348**
LEN	P	0.666**	0.551**	0.066	0.481**	0.267**	0.285**
SKLTS	G	0.857**	0.683**	0.082	0.435**	0.178	0.305**
	P	0.739**	0.608**	0.078	0.378**	0.156	0.242*
FLTS	G		0.883**	0.252*	0.597**	0.191	0.253*
	P		0.866**	0.183	0.568**	0.186	0.230*
GRNS	G			0.675**	0.734**	0.197	0.497**
	P			0.649**	0.718**	0.196	0.486**
FERT	G				0.563**	0.102	0.635**
	P				0.537**	0.098	0.612**
GRN	G					0.574**	0.431**
WT	P					0.566**	0.416**
TS WT	G						0.173
	P						0.173

spikes plant⁻¹ and yield plant⁻¹ at both genotypic and phenotypic levels also reported by Mohammadi et al. (2009) under heat stress. Grain proline content was found to have significant negative correlation with no. of spikelet spike⁻¹ at genotypic level only. No. of tillers plant⁻¹ showed highly significant positive association with no. of spikes plant⁻¹, floret fertility

and yield plant⁻¹ at genotypic as well as phenotypic level. It showed significant negative correlation with chlorophyll-a, chlorophyll-b and total chlorophyll content. No. of spikes plant⁻¹ was observed to have strong significant positive association with floret fertility and yield plant⁻¹ at genotypic and phenotypic levels which was supported by Khan et al. (2014) for spikes no. m⁻² with grain yield under late sowing condition. Spike length showed highly significant positive correlation with no. of spikelets spike⁻¹, no. of florets spike⁻¹, no. of grains spike⁻¹, grain weight spike⁻¹, test weight and yield plant⁻¹ at genotypic and phenotypic levels no. of spikelets spike⁻¹ showed highly significant correlation with no. of florets spike⁻¹, no. of grains spike⁻¹, grain weight spike⁻¹ and yield plant⁻¹ at both genotypic and phenotypic levels. The present finding was supported by Kumar et al. (2010) who noted positive correlation between no. of spikelets spike⁻¹ with no. of grains spike⁻¹, plant height and grain yield at both the levels. Floret fertility was found to have highly significant positive correlation with grain weight spike⁻¹ and yield plant⁻¹ at genotypic and phenotypic levels. Test weight showed significant positive correlation with chlorophyll-b, total chlorophyll content, spike length and grain weight spike⁻¹. But 1000 grain weight showed non-significant correlation with yield plant⁻¹. This finding was in accordance with Khan et al. (2014) who have obtained non-significant correlation (0.154) between 1000 grain weight and yield m⁻² under late sowing condition. The ultimate goal of any breeding programme is to improve yield. Yield is a complex trait and depends upon several factors. In the present investigation yield plant⁻¹ was observed to have significant positive correlation with plant height, no. of tillers plant⁻¹, no. of spikes plant⁻¹, no. of spikelets spike⁻¹, no. of florets spike⁻¹, no. of grains spike⁻¹, floret fertility and spike length and grain weight spike⁻¹ at both genotypic and phenotypic levels. Consequently to improve yield, associated components should be dealt simultaneously.

3.3. Path coefficient analysis

Path coefficient splits the amount of inter relationship into components, direct and indirect effects as exerted on dependent character (Table 3). Path coefficient analysis was based on correlation coefficient using grain yield as the dependent factor (effect) and fix other quantitative characters under study as independent factors (causes). The residual effect was found low (0.13002) estimated on pooled data, which suggested that the no. of characters chosen in the investigation was appropriate for yield determination of bread wheat under terminal heat stress.

Direct effects of days to maturity, days to flowering, total chlorophyll content, no. of tillers plant⁻¹, spike length, no. of florets spike⁻¹ and floret fertility indicated positive value. Direct effects of days to heading, plant height, flag leaf area, chlorophyll-a, chlorophyll-b, grain proline content, no. of spikes plant⁻¹, no. of spikelet spike, no. of grains spike⁻¹, grain weight spike⁻¹ and test weight was observed to have negative

Table 3: Path coefficient analysis showing direct (bold) and indirect effects estimated on pooled data of yield attributing traits on yield

Characters	DM	DH	DF	PH	FLA	CHL a	CHL b	TOT CHL	PRL	TLRS	SPKS	SP LEN	SKLTS
DM	0.151	-1.016	0.796	-0.013	0.035	0.138	0.216	-0.198	-0.036	0.033	-0.005	-0.044	0.034
DH	0.034	-4.494	3.894	-0.006	-0.044	0.147	0.191	-0.192	0.039	-0.257	0.296	0.122	-0.250
DF	0.030	-4.411	3.968	-0.003	-0.045	0.116	0.158	-0.155	0.033	-0.225	0.218	0.115	-0.187
PH	0.007	-0.094	0.045	-0.291	-0.038	0.095	-0.017	-0.054	0.061	0.440	-0.472	0.276	-0.270
FLA	-0.031	-1.166	1.057	-0.066	-0.171	0.108	0.135	-0.138	0.021	-0.076	0.004	0.267	-0.406
CHL a	-0.035	1.097	-0.767	0.046	0.031	-0.602	-0.645	0.717	-0.001	-1.479	1.174	-0.031	0.232
CHL b	-0.043	1.129	-0.823	-0.007	0.030	-0.510	-0.762	0.714	-0.014	-0.983	0.807	0.070	0.083
TOT CHL	-0.040	1.158	-0.827	0.021	0.032	-0.579	-0.731	0.744	-0.007	-1.287	1.035	0.019	0.165
PRL	0.024	0.796	-0.602	0.080	0.017	-0.001	-0.049	0.025	-0.220	-0.709	0.610	-0.074	0.312
TLRS	0.001	0.317	-0.244	-0.035	0.004	0.244	0.205	-0.262	0.043	3.654	-3.063	-0.043	0.105
SPKS	0.000	0.429	-0.279	-0.044	0.000	0.228	0.198	-0.248	0.043	3.607	-3.103	-0.038	0.125
SKLTS	-0.008	-0.654	0.546	-0.096	-0.054	0.022	-0.064	0.017	0.019	-0.188	0.140	0.839	-1.191
FLTS	-0.004	-0.766	0.507	-0.054	-0.047	0.095	0.043	-0.084	0.047	-0.261	0.265	0.682	-1.466
GRNS	-0.013	-0.672	0.388	-0.102	-0.075	0.024	-0.049	0.008	0.034	-0.589	0.484	0.637	-1.255
FERT	-0.015	0.177	-0.353	-0.122	-0.054	0.102	0.013	-0.073	0.014	0.367	-0.311	0.539	-1.002
GRN WT	-0.008	1.400	-1.327	-0.097	0.008	0.176	0.102	-0.167	-0.024	1.683	-1.399	0.107	-0.120
TS WT	-0.005	1.447	-1.224	-0.102	-0.034	-0.028	-0.156	0.096	-0.013	0.173	-0.165	0.481	-0.638
YLD	0.005	1.620	-1.307	-0.008	0.007	-0.113	-0.194	0.170	-0.025	-0.061	0.037	0.261	-0.261

Table 3: Continue...

Characters	FLTS	GRNS	FERT	GRN WT	TS WT	YLD
DM	-1.001	1.290	-0.336	0.005	-0.005	0.046
DH	1.752	0.527	-2.015	0.052	0.051	-0.152
DF	1.145	1.187	-2.163	0.050	0.047	-0.121
PH	4.108	-5.613	2.158	-0.057	-0.004	0.279**
FLA	5.186	-4.223	-0.288	-0.032	0.006	0.189
CHL a	-0.469	2.254	-1.892	-0.007	-0.027	-0.409**
CHL b	0.748	0.232	-0.867	-0.033	-0.036	-0.268**
TOT CHL	0.131	1.317	-1.448	-0.021	-0.032	-0.354**
PRL	-1.825	0.827	0.708	-0.009	-0.016	-0.106
TLRS	-1.890	-1.342	2.980	-0.008	0.002	0.669**
SPKS	-1.828	-1.339	2.917	-0.009	0.002	0.664**
SKLTS	8.903	-8.576	0.828	-0.092	-0.044	0.348**
FLTS	10.044	-9.132	0.529	-0.070	-0.025	0.305**
GRNS	11.725	-11.799	1.631	-0.096	-0.027	0.253*
FERT	10.354	-13.361	4.368	-0.118	-0.028	0.497**
GRN WT	2.956	-9.022	6.469	-0.091	-0.015	0.635**
TS WT	7.002	-9.806	3.644	-0.161	-0.081	0.431**
YLD	2.244	-2.631	0.662	-0.092	-0.142	0.173

**Significant at ($p=0.01$); *Significant at ($p=0.05$); Residual effect=0.13002; GC-Genotypic correlation

value. These above findings were partially supported by Iftikhar et al. (2012). Days to flowering indicated a greater positive direct effect but it was negatively correlated with yield. This finding is fully supported by Gelalcha and Hanchinal (2013). The negative correlation was due to the indirect effects of days to heading, plant height, flag leaf area, total chlorophyll content, no. of tillers plant⁻¹, no. of spikelets spike⁻¹ and floret fertility. Total chlorophyll content indicated positive direct effect whereas it showed highly significant negative correlation with yield. The negative correlation was due to the indirect effects of days to maturity, days to flowering, plant height, chlorophyll-a, chlorophyll-b, proline content, no. of tillers plant⁻¹, floret fertility, grain weight spike⁻¹, and test weight. A restricted selection model should be followed to nullify the undesirable indirect effects. Spike length indicated high positive direct effect along with high significant positive correlation. No. of tillers plant⁻¹, no. of florets spike⁻¹, floret fertility attained a greater magnitude of direct effect than its correlation coefficient indicating more indirect influence of the trait via other components. In case of tillers plant⁻¹, floret fertility was the reason for greater direct effect. No. of tillers plant⁻¹ and no. of florets spike⁻¹ was the roots of greater direct effect of floret fertility. Present study revealed that, no. of tillers plant⁻¹, spike length, no. of florets spike⁻¹, floret fertility are simultaneously selected for advancement of yield under terminal heat stress. As wheat plants under heat stress use stem

reserve, plant height was observed to have positive correlation with yield with negative direct effects. So dwarf plants with thick stem and indirect causal factors may be selected for increase in yield under late heat stress. No. of spikes plant⁻¹ indicated negative direct effect but high significant positive correlation. The positive association was due to indirect effects of days to heading, chlorophyll-a, chlorophyll-b, proline content, no. of tillers plant⁻¹, and no. of spikelets spike⁻¹, floret fertility and test weight. So no. of spikes plant⁻¹ is selected along with the indirect causal factors. No. of grains spike⁻¹ reported to have negative direct effect but high significant correlation. Days to heading, chlorophyll-a, chlorophyll-b, no. of tillers plant⁻¹, spike length, no. of florets spike⁻¹, floret fertility were the causes of positive association. So this parameter is selected including indirect causal factors as previously supported by Oulmi et al. (2014). Grain weight spike⁻¹ illustrated significant positive correlation with yield plant⁻¹ with negative direct effect. Therefore, grain weight spike⁻¹ may be selected along with floret fertility, no. of florets spike, spike length, days to heading due to their greater positive indirect effects. Similarly Choudhary et al. (2014) had taken Spikelet fertility, no. of grains spike⁻¹, no. of effective tillers plant⁻¹ and pollen sterility as selection criteria.

4. Conclusion

Stabilizing selection should be followed for accumulation of alleles exhibiting additive gene action. A restricted simultaneous selection model should be followed for grain weight spike⁻¹, no. of grains spike⁻¹, no. of spikelets spike⁻¹ and no. of spikes plant⁻¹. Shuttle breeding programme may be conducted in order to get better adaptation of wheat to terminal heat stress in this era of global climate change.

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