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Effect of temperature stress studies on various biological growth parameters in wheat genotypes under semi-natural conditions

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Abstract: Grain yield of wheat in Pakistan is low as it is severely affected by various biotic and abiotic stresses. Among the abiotic stress, heat stress (terminal high temperature) is one of the major causes of low wheat productivity in Pakistan. This paper focuses on the evaluation and performance of newly evolved wheat genotypes under different temperature regimes and the selection of suitable promising lines. Experiment was conducted under semi-natural conditions on twenty wheat genotypes (DH-1, DH-3, DH-4, DH-5, DH-6, DH-7, DH-8, DH-10, DH-11, DH-12, DH-13, DH-14, DH-15, DH-16, DH-18, DH-19, DH-20, DH-21, Lu-26s and Kiran-95) in wire gauze chambers at Nuclrear Institute of Agriculture, Tandojam, Sindh, Pakistan, during 2014-15. The genotypes were sown in three different dates viz., S1 (November 7, as optimum condition), S2 (November 27 as heat stress) and S3 (December 17 as high heat stress). All the plant growth parameters viz., plant height (cm), productive tillers plant^{-1}, spike length (cm), spiklets spike^{-1}, number of grain spike^{-1}, grain weight plant^{-1} and 1000-grain weight (g) exposed significant variation among genotypes and temperature regimes based on their interactions and these showed significantly decreasing trend in heat stress conditions over optimum conditions. The genotypes DH-8, DH-11, DH-15, DH-19 and Lu-26s classified as tolerant exhibiting <50% reduction in 7 variables whereas, DH12 and Kiran-95 were sensitive showing <50% reduction in 4 variable. The genotypes DH-1, DH-4, DH-5, DH-6, DH-7, DH-13, DH-16, DH-18 were medium tolerant showing <50% reduction in 6 variables while DH-3, DH-10, DH-12, DH-14, DH-20 were found medium sensitive showing <50% reduction in 5 variables.

Keywords: Temperature, wheat, growth, biochemical, semi-nature

1. INTRODUCTION

Wheat is the foremost food stuff grains of Pakistan and personality the core diet of the fill and occupies a predominant point in cultivation policies. Wheat contributes 9.1 percent to the significance added in agriculture and 1.7 percent to GDP of Pakistan. Wheat production was estimated at 25.492 million tonnes during 2017-18, recorded to decline of 4.4 percent over the last year's production of 26.674 million tonnes. The construction better as it should be to develop reserve of put in which contributed in enhancing for per hectare yield (GOP, 2018). Between varies factors accountable for near to the low yield of wheat crop in the country, sowing time and varietal collection are of key importance. Wheat is sown in winter season and its be in possession of sure rations for temperature and light for emergence, development and flowering (Dabre *et al., 1993)*

The inspire of high temperature on enlargement and enhancement of wheat and other crops is attractively recognized (Porter and Gawith, 1999; Wheeler *et al.*, 2000). High temperature is highly injure photosynthetic membranes (thylakoids) and basis chlorophyll loss (Al-Khatib and Paulsen, 1984), decrease leaf photosynthetic rate and increase embryo absorption (Saini *et al.*, 1983), small number grains and drop off grains filling duration and rates (Wardlaw and Moncur, 1995; Wheeler *et al.*, 1996; Ferris *et at.*, 1998; Prasad and Allen, 2006) hence resulting in low grains yield (Wardlaw *et al.*, 1989; Stone and Nicolas, 1994; Wheeler *et al.*, 1996; Gibson and Paulsen, 1999). Grains yield in wheat at 2^0C warming strength look up by 12% appropriate to longer crop duration but a 4^0C warming would decreasing overall production. (Narayanan *et al.* 2015) measured a high heat as the foremost environment factors that confine the wheat crop production. Many selection criteria base on morphological, physiological and biochemical traits have suggested for screening heat tolerance in wheat for example, slay green or longer leaf chlorophyll retention, stomatal conductance (Jones, 1977), stomatal number (Kazemi *et al.*, 1978), canopy hotness despair (Blum *et al.*, 1982), excised-leaf water loss (Clark and McCaig, 1982), osmo-regulation (Morgan, 1983), Chlorophyll fluorescence (Moffat *et al.*, 1990), membrane thermo-stability (Pronay *et al.*, 2017) and seeds endosperm utilization (Blum and Sinmena, 1994). Observing in view the above facts, the organized investigation was initiated with the objective to screen better performance of wheat genotypes in wire netted-house (Semi-controlled) under different temperature based on varies growth parameters.

2. MATERIALS AND METHODS

The experiment was conducted in RCBD factorial arrangement with three replications. Eighteen double

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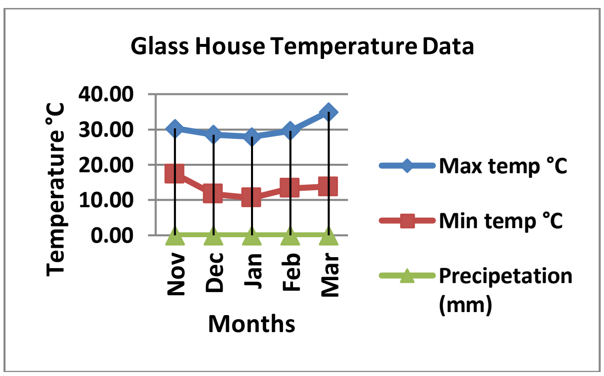
haploid wheat genotypes and two commertial varieties as check, i.e., Kiran-95 from NIA Tandojam and another and Lu-26s from University od Agriculture, Faisalabad were sown under three dates of sowing i.e., S1 as optimum condition (7th November 2014), S2 as heat stress (27 th November 2014; after 20 days gaps from optimum condition) and S3 as high heat stress (17 th December 2014; after 40 days gaps from optimum condition). Separate wire gauze cabnit was used for each sowing date. The row length was kept as 1.5 m. The plant to plant and row to row space was considered as 10 cm and 20 cm, respectively. Data on various morphological (plant height, productive tillers plant^{-1}, spike length, spiklets spike^{-1}, number of grain spike^{-1}, grain weight plant^{-1} and 1000-grain weight) were recorded to assess the effect of high temperature on yield contributing traits. Temperature data were also recorded at experimental station during cropping season to assess heat shocks or high temperature effects during grain filling stage (terminal heat shocks) and genotype response to these shocks due to late sowing. Statistical analysis of data was performed through computer software MSTAT-C.

Fig 1:Temperature data recorded in glass house experiment at NIA, Tandojam during wheat Season 2014-15 years.



3. <u>RESULTS</u>

3.1. Plant height (cm)

The results **(Table 1, Column A)** revealed significant difference based on interactions among genotypes and sowing dates at different temperature conditions. The genotype DH-8 showed maximum plant height i.e. 99.67 cm in S1, while minimum i.e., 72.68 cm was recorded in DH-21. Under heat stress condition (S-2), the genotype DH-3 showed significantly maximum plant height i.e. 82.33 cm and minimum 71.67 cm was found in DH-4. Under high heat stress condition (S-3), the genotype DH-3 showed significantly maximum plant height i.e. 76.00 cm, whereas DH-16 showed minimum plant height i.e. 53.17 cm. Percent reduction in plant height at high heat stress condition over optimum, the genotype DH- 16 showed maximum reduction i.e. 35.30 percent followed by DH-8, DH-21, DH-6, DH-10, DH-12 and Kiran-95 having 31.77, 25.70, 25.17, 20.53, 20.60 and 22.94 percent reduction in plant height, respectively and these varieties were found to be sensitive. The minimum percent reduction at high heat stress condition in plant height was recorded to be 10.93 cm in DH-3. The effect of temperature conditions on an average in all the genotypes was significant (Last row of Column A). Optimum condition showed maximum plant height i.e., 81.37cm and it was significantly decreased as the temperature stress increased.

3.2. Productive tillers plant^{-1}

The results (Table 1, Column B) revealed that the maximum productive tillers plant^{-1} were observed in DH-1, DH-4, DH-5, DH-6, DH-12, DH-16, DH-18 and DH-20 each showing 3.00 per plant and were non-significant in optimum condition (S-1). These genotypes were also at par statistically with those of DH-8, DH-11, DH-15 and DH-19 with 2.89, 2.67, 2.83, and 2.89 per plant productive tillers, respectively. The minimum productive tillers were recorded to be 2.22 per plant in DH-13. In case of heat stress condition (S-2) the genotype DH-12 and DH-1 showed maximum productive tillers plant^{-1} i.e. 2.67 and 2.48 per plant, respectively. The minimum productive tillers were recorded to be 2.00 per plant in DH-13. In case of high stress condition (S3), the genotype DH-1 had maximum productive tiller i.e. 2.33 per plant and DH-3, DH-5, DH10, and DH-13 showed minimum productive tillers each showed 1.83 per plant. Furthermore, the genotype DH-5 showed maximum reduction in high heat stress conditions over optimum conditions with 39.00% productive tillers plant^{-1}, respectively and this genotype was found to be sensitive, whereas minimum percent reduction in productive tillers plant^{-1} was recorded to be 11.07% in Lu-26s under high heat stress condition over optimum and found tolerant.

3.3. Spike length (cm)

The results **(Table, 1, Column C)** revealed that spike length at optimum conditions (S1) was significantly maximum as compared to heat stress (S2) and high heat stress condition (S3) in all the genotypes. Furthermore, maximum reduction in spike length at high heat stress conditions was 50.14 percent in DH-21 and declared as sensitive. In high heat stress condition, DH-10 showed the minimum reduction (20.21%) and was found sensitive. The effect of temperature conditions on an average basis in all the genotypes had significant difference (Table 1, last row, Column C). Optimum condition showed significantly maximum spike length (10.05 cm) followed by 8.65 and 6.3 cm in heat stress and in high heat stress conditions, respectively.

3.4. Spikelets spike^{-1}

Significant difference was found to exist among genotypes and temperature conditions on the basis of their interactions (Table 1, Column D). It is evident from the results that optimum condition had significantly the maximum number of spikelets spike^{-1} in all the genotypes compared with heat stress and high heat stress conditions. The genotype DH-12 showed maximum reduction of 53.84 percent followed by DH-1 (50.04%), DH-6 (50.00%) and DH 14 (50.76%) in high heat stress condition and categorized as sensitive genotypes. The minimum reduction in spikelets was recorded to be 14.27 percent in genotype DH-10 and was tolerant.

3.5. Number of grains spike^{-1}

The results (Table 1, Column E) revealed that DH-12 showed significantly maximum number of grain i.e. 53.48 per spike at optimum condition (S-1) it was minimum 31.15 per spike on Lu-26s. In case of heat stress condition (S-2) the genotype DH-5 showed maximum number of grains i.e. 45.67 per spike and DH-12 (44.47 per spike). The genotype Kiran-95 possessed significantly minimum number of grains i.e. 22.75 per spike. Similarly at high heat stress conditions (S-3), DH-20 showed maximum number of grains i.e. 38.25 per spike and while the number of grains was found to be minimum i.e. 12.68 per spike in genotype DH-21. In high heat stress condition over optimum condition DH-21 showed maximum reduction in number of grains i.e. 62.55 percent and proved to be a sensitive genotype. The genotype DH-20 showed minimum reduction i.e. 14.01 percent in high heat stress condition over optimum condition and categorized as a tolerant genotype.

3.6. Grain weight plant^{-1} (g)

Significant variation was found to exist among genotypes and various temperature conditions regarding grain weight plant^{-1} **(Table 1, Column F).** It is evident from the results that at optimum conditions (S-1), the genotype DH-20 possessed maximum grain weight i.e. 8.43 gram per plant and did not show significant difference with those of DH-10 having 8.21 gram grain weight per plant, while it was minimum in DH-15 i.e. 6.50 gram per plant and did not show significant difference with those of observed in most of the genotypes. At heat stress condition (S-2) the maximum grain weight was recorded to be 5.77 gram per plant in genotype DH-21 and did not show significant variation. The minimum grain weight was recorded to be 4.70 gram per plant in genotype DH-13 and also showed non-significant variation. At high heat stress condition (S-3) the genotype DH-19 possessed maximum grain weight i.e. 4.30 gram per plant and the minimum grain weight was recorded to be 3.11 gram per plant in DH-3 and didnot show significant variation, respectively. At high heat stress condition the genotype DH-10 showed 60.54 percent reduction which was the maximum and categorized as sensitive genotype whereas DH-11 with minimum reduction in grain weight i.e. 37.92 percent categorized as tolerant.

3.7. 1000-grain weight (g)

Significant variation was found to exist among genotypes and various temperature conditions regarding 1000-grain weight (g) based on their interactional responses (Table 1, Column G). The results revealed that significantly maximum 1000-grain weight was recorded to be 62.50 gram in DH-21. The minimum 1000-grain weight was observed in DH-12 i.e. 32.85 gram and was at par statistically with those of observed in DH-6 and DH-11 with 32.06 and 33.74 gram 1000-grain weight, respectively. Under heat stress condition (S-2) the maximum 1000-grain weight was found to be 47.76 gram in DH-16, while it was minimum in DH-10 i.e. 23.77 gram. At high heat stress condition (S-3) the genotype DH-21 possessed maximum 1000-grain weight i.e. 35.79 gram while it was minimum in DH-3 with 15.00 gram and was at par statistically with those of found in DH-10 showing 15.48 gram 1000-grain weight. The maximum reduction in 1000-grain weight was calculated to be 61.80 percent in DH-3 under high heat stress condition and this genotype was found to be sensitive whereas minimum reduction i.e. 28.02 percent found in DH-8 and was appeared as tolerant.

3.8. Ranking of tolerant and sensitive wheat genotypes based on < 50% reduction in variables studied at high heat stress over optimum conditions.

The results are summarized in **(Table 1,2 and 3)** for categorization of genotypes of wheat as tolerant and sensitive responses. The genotypes DH-8, DH-11, DH-15, DH-19 and Lu26s were proved to be tolerant as these showed < 50% reduction in 7 variables at high heat stress over optimum conditions. Two genotypes i.e., DH-21 and Kiran-95 were sensitive as these showed <50% reduction in 2 variables. Eight genotypes viz., DH-1, DH-4, DH-5, DH-6, DH-7, DH-13, DH-16 and DH-18 were appeared as medium tolerant in which 6 variables were showed < 50% reduction at high heat stress over optimum conditions. There were 5 genotypes viz., DH-3, DH-10, DH-12, DH-14 and DH-20 which showed medium sensitive response as there were 5 variables which showed < 50% reduction at high heat stress conditions. Thus out of 20 genotypes 5 were tolerant, 8 medium tolerant, 5 medium sensitive and 2 were sensitive under high stress condition over optimum condition.

Table 1: Effect of temperature conditions on various biological yield parameters in different genotypes of wheat under semi-natural conditions.

Genotypes	Plant height (cm) (A)				Productive tillers plant^{-1} (B)				Spike length (cm) (C)			
	Interactional Response (LSD at 5% = 1.769)			Reduction in high heat stress condition over optimum condition (%)	Interactional Response (LSD at 5% = 0.250)			Reduction in high heat stress condition over optimum condition (%)	Interactional Response (LSD at 5% = 0.580)			Reduction in high heat stress condition over optimum condition (%)
	S1	S2	S3		S1	S2	S3		S1	S2	S3	
DH-1	78.67 JKLMN	73.00 UVW	67.50 Z[\	14.20	3.00 A	2.48 CDEF	2.33 EFGHI	22.33	9.91 FGH	9.53 GHIJ	5.56 WXYZ	43.90
DH-3	85.33 CD	82.33 EF	76.00 OPQR	10.93	2.33 EFGHI	2.22 FGHI	1.83 J	21.46	9.81 FGHI	8.95 JKLM	7.40 RST	24.57
DH-4	73.17 UVW	71.67 VW	62.00 ab	15.27	3.00 A	2.17 FGHIJ	2.00 IJ	33.33	9.42 HIJK	8.45 MNO	6.24 V	33.76
DH-5	86.83 BC	79.50 IJKLM	72.83 UVW	16.12	3.00 A	2.00 IJ	1.83 J	39.00	10.92 BCD	10.33 DEF	7.83 OPQR	28.30
DH-6	81.50 FGHI	75.67 PQRS	61.00 bc	25.15	3.00 A	2.28 EFGHI	2.17 FGHIJ	27.67	9.75 FGHI	9.43 HIJK	5.40 XYZ[	44.62
DH-7	76.17 OPQ	64.83]ʌ	59.67 c	21.66	2.28 EFGHI	2.17 FGHIJ	2.00 IJ	12.28	9.19 IJKL	7.81 OPQR	4.90 Z[	46.68
DH-8	99.67 A	80.17 GHIJK	68.00 YZ[	31.77	2.89 AB	2.33 EFGHI	2.17 FGHIJ	24.91	9.17 IJKL	6.87 TU	4.86 [	47.00
DH-10	87.67 B	81.67 FGH	69.67 XY	20.53	2.44 CDEFG	2.06 HIJ	1.83 J	25.00	11.28 B	10.42 CDEF	9.00 JKLM	20.21
DH-11	80.17 GHIJK	76.67 NOP	65.67 \] ʌ	18.09	2.67 ABC	2.33 EFGHI	2.00 IJ	25.09	8.75 KLMN	7.23 RST	5.46 WXYZ[	37.60
DH-12	78.50 KLMN	74.17 QRSTU	62.33 ‘ab	20.60	3.00 A	2.67 ABCD	2.00 IJ	33.33	10.33 DEF	9.92 FGH	5.42 XYZ[	47.53
DH-13	74.06 RSTU	72.50 UVW	64.26 ʌ	13.23	2.22 FGHI	2.00 IJ	1.83 J	17.57	9.33 HIJKL	8.13 NOPQ	7.06 ST	24.33
DH-14	80.67 FGHIJ	78.33 KLMN	67.50 Z[\	16.33	2.39 CDEFGH	2.22 FGHI	2.00 IJ	16.32	10.00 EFGH	8.36 MNOP	5.00 YZ[	50.00
DH-15	83.72 DE	82.00 EFG	69.67 XY	16.78	2.83 AB	2.33 CDEFGHI	2.11 GHIJ	25.44	9.19 IJKL	7.72 PQRS	6.11 VW	33.51
DH-16	82.18 EFG	69.29 YZ	53.17 d	35.30	3.00 A	2.27 EFGHI	2.00 IJ	33.33	11.00 BC	7.73 PQRS	6.33 UV	42.45
DH-18	77.51 MNOP	74.34 QRSTU	63.50 _’a	18.08	3.00 A	2.16 IJ	2.00 IJ	33.33	10.17 EFG	8.68 LMN	7.09 ST	30.29
DH-19	75.50 PQRST	73.79 STU	66.67 [\]	11.70	2.89 AB	2.33 CDEFGHI	2.17 FGHIJ	24.91	8.97 JKLM	7.85 OPQR	5.72 VWXY	36.23
DH-20	86.33 BC	77.99 LMNO	71.33 WX	17.38	3.00 A	2.33 EFGHI	2.00 IJ	33.33	12.08 A	11.08 BC	7.63 QRS	36.84
DH-21	72.68 UVW	64.17 ʌ	54.00 d	25.70	2.50 CDEF	2.17FGHIJ	2.00 IJ	20.00	11.03 BC	9.02 JKLM	5.50 VWXY	50.14
Lu-26s	85.68 C	79.83HIJKL	73.50 TUV	14.22	2.44 CDEFG	2.33DEFGHI	2.17 FGHIJ	11.07	10.11 EFG	9.50 GHIJ	7.72 PQRS	23.64
Kiran-95	81.33 FGHI	76.02 PQR	62.67 ‘ab	22.94	2.61 BCDE	2.28 EFGHI	2.00 IJ	23.37	10.67 BCDE	8.29 NOPQ	6.07 YWX	43.11
Means	**81.37 A**	**75.40 B**	**65.55 C**		**2.73 A**	**2.26 B**	**2.02 C**		**10.05 A**	**8.65 B**	**6.32 C**	
(LSD at 5%	**0.395**				**0.062**				**0.129**			

Genotypes	Number of spkilets spike^{-1} (D)				Number of grains plant^{-1} (E)				Grain weight per plant (g) (F)			
	Interactional Response (LSD at 5% = 0.766)			**Reduction in high heat stress condition over optimum condition (%)**	**Interactional Response (LSD at 5% = 2.094)**			**Reduction in high heat stress condition over optimum condition (%)**	**Interactional Response (LSD at 5% = 0.454)**			**Reduction in high heat stress condition over optimum condition (%)**
	S1	**S2**	**S3**		**S1**	**S2**	**S3**		**S1**	**S2**	**S3**	
DH-1	14.11 DEFGHIJ	13.33 JKLMN	7.05 \]	50.04	37.69JK	34.42 LM	23.94 WXY	36.48	6.84 CDEF	5.33 GHIJK	3.88 PQRS	36.48
DH-3	14.64 DEFG	13.83 FGHIJKL	9.78 UV	33.20	41.09 GHI	32.33 MNO	27.97 RST	31.93	6.65 DEF	5.30 GHIJKL	3.11 V	31.93
DH-4	14.0 EFGHIJKL	13.25 JKLMNO	8.19 XYZ	41.50	39.15 IJ	29.53 PQR	25.05 UVWX	36.02	6.44 F	4.94 JKLMN	3.65 QRSTU	36.02
DH-5	15.00 CD	14.75 CDEF	10.28 TU	31.47	46.65 C	45.67 CD	32.36 MNO	30.63	7.72 B	5.21 HIJKLMN	3.79 PQRST	30.63
DH-6	14.06 EFGHIJK	13.69 HIJKLM	7.03 [\]	50.00	41.04 GHI	39.44 IJ	24.97 UVWX	39.16	6.96 CDEF	5.48 GHIJ	3.68 QRSTU	39.16
DH-7	12.39 OPQ	11.19 RS	6.69]	46.00	41.98 FGH	31.69 NOP	19.61 [\	53.29	6.57 EF	4.96 JKLMN	3.54 QRSTUV	53.29
DH-8	13.14 KLMNO	10.81 ST	6.69]	49.09	34.73 LM	26.19 TUVW	17.64]^	49.21	6.91 CDEF	4.74 MNO	3.53 RSTUV	49.21
DH-10	16.33 AB	15.89 AB	14.00 FGHIJKL	14.27	46.09 C	43.17 EFG	35.20 L	23.63	8.21 A	4.76 LMNO	3.24 UV	23.63
DH-11	12.67 NOPQ	11.08 ST	7.33 [\]	42.15	38.75 IJ	34.67 LM	22.39 YZ	42.22	6.54 EF	5.27 GHIJKLM	4.06 PQ	42.22
DH-12	16.01 AB	14.91 CDE	7.39 Z[\]	53.84	53.48 A	44.47 CDE	26.14 TUVW	51.12	7.20 C	5.58 GHI	4.28 OP	51.12
DH-13	14.47 DEFGHI	13.42 JKLMN	9.39 VW	35.11	34.32 LM	29.58 PQR	27.33 RSTU	20.37	6.53 EF	4.70 NO	3.32 TUV	20.37
DH-14	14.50 DEFGH	12.11 PQ	7.14 [\]	50.76	34.65 LM	27.97 RST	18.39 \]	46.93	6.52 EF	4.91 KLMN	3.65 QRSTU	46.93
DH-15	13.08 LMNO	10.72 ST	8.00 XYZ[	38.84	34.29 LM	26.92 STU	20.97 Z[	38.85	6.50 F	5.20 HIJKLMN	3.99 PQR	38.85
DH-16	15.58 BC	11.92 QR	8.78 WX	43.65	38.82 IJ	26.50 TUV	15.53 ^	59.99	6.90 CDEF	5.65 GH	3.70 QRSTU	59.99
DH-18	15.00 CD	13.36 JKLMN	8.83 WX	41.13	49.15 B	35.83 KL	28.97 QRS	41.06	7.06 CDE	5.28 GHIJKLM	4.01 PQR	41.06
DH-19	13.78 GHIJKL	11.25 RS	7.86 YZ[\	42.96	39.84 HIJ	35.94 KL	24.19 VWXY	39.28	6.98 CDEF	5.73 GH	4.30 OP	39.28
DH-20	16.55 A	14.0 EFGHIJKL	13.56 IJKLMN	18.07	44.48 CDE	41.92 FGH	38.25 J	14.01	8.43 A	5.41 GHIJK	3.81 PQRST	14.01
DH-21	15.56 BC	13.83 FGHIJKL	8.33 XY	46.47	33.82 LMN	31.03 OPQ	12.68 _	62.51	7.13 CD	5.77 G	3.16 UV	62.51
Lu-26s	14.72 CDEF	14.11 DEFGHIJ	9.89 UV	32.81	31.15 OPQ	26.14 TUVW	22.47 YZ	27.87	6.52 EF	5.03 JKLMN	3.37 STUV	27.87
Kiran-95	14.92 CDE	12.82 MNOP	8.28 XY	44.50	43.48 DEF	22.75 XYZ	21.14 Z[	51.38	6.86 CDEF	5.06 IJKLMN	3.20 UV	51.38
Means	**14.52 A**	**13.02 B**	**8.72 C**		**40.23 A**	**33.31 B**	**24.21 C**		**6.97 A**	**5.22 B**	**3.66 C**	
(LSD at 5%	**0.171**				**0.486**				**0.101**			

Genotypes	1000-grain weight (g) (G)			
	Interactional Response (LSD at 5% =1.346)			**Reduction in high heat stress condition over optimum condition (%)**
	S1	**S2**	**S3**	
DH-1	38.84 HI	29.81 TUV	20.81 Z	46.42
DH-3	39.27HI	26.63 WX	15.00]	61.80
DH-4	40.82 FG	26.91 W	18.69 [\	54.21
DH-5	42.34 E	25.29 X	22.59 Y	46.65
DH-6	32.06 QR	29.95 STU	19.53 Z[	39.08
DH-7	38.58 HIJK	28.81 UV	23.42 Y	39.29
DH-8	42.43 E	37.21 KLM	30.54 ST	28.02
DH-10	36.83 LMN	23.77 Y	15.48]	57.97
DH-11	33.74 O	31.25 RS	25.75 WX	23.68
DH-12	32.85 OPQ	28.33 V	18.89 [\	42.50
DH-13	37.84 IJKL	29.32 TUV	17.80 \	52.96
DH-14	41.17 EF	38.08 HIJKL	23.28 Y	43.45
DH-15	39.18 HI	33.59 OP	25.32 X	35.38
DH-16	49.58 B	47.76 C	29.96 STU	39.57
DH-18	41.43 EF	32.25 PQR	19.85 Z[	52.09
DH-19	38.72 HIJ	36.21 MN	23.77 Y	38.61
DH-20	37.20 JKLM	25.45 WX	18.35 [\	50.67
DH-21	62.50 A	45.65 D	35.79 MN	42.74
Lu-26s	39.56 GH	28.85 UV	20.59 Z	47.95
Kiran-95	35.39 N	29.13 TUV	17.57 [\	50.35
Means	**40.02 A**	**31.71 B**	**22.15 C**	
(LSD at 5%	**0.300**			

Similar letters in columns and rows are not significantly different by DMR test at P = 0.05

Table 2: Wheat genotypes categorized on the bases of < 50% reduction at high heat stress (Wire gauze chamber studies)

S.No.	Genotypes	Plant height (cm)	Productive tillers plant^{-1}	Spike length (cm)	No. of spikelets spike^{-1}	No. of grains spike^{-1}	Grain wt. plant^{-1} (g)	1000 grains wt. (g)	No. of variables
1	DH-1	+	+	+	-	+	+	+	6
2	DH-3	+	+	+	+	+	-	-	5
3	DH-4	+	+	+	+	+	+	-	6
4	DH-5	+	+	+	+	+	-	+	6
5	DH-6	+	+	+	-	+	+	+	6
6	DH-7	+	+	+	+	-	+	+	6
7	DH-8	+	+	+	+	+	+	+	7
8	DH-10	+	+	+	+	+	-	-	5
9	DH-11	+	+	+	+	+	+	+	7
10	DH-12	+	+	+	-	-	+	+	5
11	DH-13	+	+	+	+	+	+	-	6
12	DH-14	+	+	-	-	+	+	+	5
13	DH-15	+	+	+	+	+	+	+	7
14	DH-16	+	+	+	+	-	+	+	6
15	DH-18	+	+	+	+	+	+	-	6
16	DH-19	+	+	+	+	+	+	+	7
17	DH-20	+	+	+	+	+	-	-	5
18	DH-21	+	+	-	+	-	-	+	4
19	Lu-26s	+	+	+	+	+	+	+	7
20	Kiran-95	+	+	+	+	-	-	-	4

Table: 3: Categorization of wheat genotypes on the basis of tolerance level

Categories	**Bases on**	**Genotypes**
Tolerant	< 50 % reduction in 07 variables	DH-8, DH-11, DH-15, DH-19, Lu-26s
Medium Tolerant	< 50 % reduction in 06 variables	DH-1, DH-4, DH-5, DH-6, DH-7, DH-13, DH-16, DH-18
Medium Sensitive	< 50 % reduction in 05 variables	DH-3, DH-10, DH-12, DH-14, DH-20
Sensitive	< 50 % reduction in 04variables	DH-21, Kiran-95

Wheat genotypes tested for temperature tolerance based on < 50% reduction at high heat stress (semi-natural) conditions.

Genotypes tested:	20
Tolerant genotypes:	05
Medium Tolerant:	08
Medium Sensitive:	05
Sensitive:	02**4.**

4. DISCUSSION

Keeping in view the above results that all the biological growth parameters i.e., plant height (cm), productive tillers plant^{-1}, spike length (cm), spikelets spike^{-1}, number of grains spike^{-1}, grain weight plant^{-1} and 1000-grain weight showed significant variation based on interactions among genotypes and various temperature conditions. Late sown wheat under high stress condition resulted in significantly adverse effect over optimum condition in all the biological parameters. The present findings are in consistency with those of Ehdaie *et al.* (1988) who also reported that heat stress condition showed negative correlation with grain per spike, grain weight and grain yield. Conclusively it was observed that five genotypes viz., DH-8, DH-11, DH-15, DH-19 and LU-26s showed tolerant response as these possessed < 50 percent reduction in seven variables whereas two genotypes DH-21 and Kiran-95 were classified sensitive as these possessed < 50 percent reduction in four biological variables. The genotypes DH-1, DH-4, DH-5, DH-6, DH-7, DH-13, DH-16 and DH-18 categorized as medium tolerant as these showed 50 percent reduction in six variables. Similarly five genotypes viz., DH-3, DH-10, DH-12, DH-14 and DH-20 classified as medium sensitive as they possessed <50 percent reduction in five variables. The present findings cannot be compared with those of Barma *et al.* (1990), Amin *et al*. (1992), Balota *et al*. (1993), Reynolds *et al.* (1994), Rahman (1996) and Reynolds *et al*. (1997 & 2000) due to variation in their materials and methods as well as ecological conditions. The present findings are in line but cannot be compared with the present findings as they studied different wheat genotypes as those of studied in the present dissertation.

5. CONCLUSION

- Plant height, productive tillers per plant, spike length, spikelets per spike, number of grain per spike, grain weight per spike, 1000-grain weight, and grain yield were suffered adversely in heat stress conditions.
- Five genotypes viz. DH-8, DH-11, DH-15, DH-19 and Lu26s were appeared as tolerant as these delineated < 50 % reduction in values of seven variables while two genotypes viz. DH-21 and Kiran-95 exposed as sensitive as these displayed < 50 % reduction in four variables.

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