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Evaluation of Bread Wheat Genotypes Using Various Stress Indices for Heat Resilience

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ABSTRACT

The present study was conducted during *rabi* seasons (November to April of 2022–2023 and 2023–2024) at Research Area of the Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana, India to evaluate 205 wheat genotypes, including five checks in augmented design under normal (timely sown) and heat stress (late sown) conditions for heat resilience using six stress indices. Results revealed a significant reduction in grain yield under heat stress conditions. Six stress indices viz. heat susceptibility index, mean productivity, tolerance, stress tolerance index, yield stability index and yield index were calculated based on grain yield under timely and late sown conditions to classify genotypes into tolerant and susceptible categories. Correlation analysis indicated a positive and highly significant association between grain yield under timely sown conditions and heat susceptibility index, mean productivity, tolerance, stress tolerance index and yield index whereas a negative and highly significant association was observed with yield stability index. Conversely, grain yield under heat stress conditions was positively and significantly correlated with yield stability index, mean productivity, tolerance, stress tolerance index and yield index but negatively and significantly associated with heat susceptibility index. Based on heat susceptibility index, 119 genotypes were classified as heat-tolerant and 86 as heat-susceptible ones. Among the tested genotypes, Raj 2184 exhibited the highest heat tolerance whereas HUW 12 was the most heat-sensitive. Therefore, genotype Raj 2184 could be effectively utilized in breeding programs for developing heat-tolerant wheat varieties, cultivation under high-temperature conditions and as a genetic resource for enhancing stress tolerance in wheat.

KEYWORDS: Heat stress, grain yield, stress tolerance index, wheat

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1. INTRODUCTION

Wheat (*Triticum aestivum* L., 2n=6x=42, AABBDD) is a staple cereal crop that holds immense global importance as it is the second-largest source of protein and calories after rice for human consumption and livestock feed (Braun et al., 2010; Naveen et al., 2024). The member of subtribe Triticinae of tribe Triticeae in Poaceae family, wheat is often referred to as the "King of Cereals" due to its remarkable adaptability to diverse agroclimatic conditions, high nutritional value, and significant yield potential (Bhanu et al., 2018; Antim et al., 2022; Mitra et al., 2024). Globally, wheat cultivation spans approximately 222.88 million hectares, accounting for 21.8% of the total cultivated area and 35.5% of total food grain production, with an annual production of about 788.95 mt (Anonymous, 2024). To meet future food demands, Food and Agriculture Organization (FAO) projects an additional requirement of 198 million tonnes of wheat by 2050, necessitating an annual production growth rate of 2.5% (Sharma et al., 2015).

However, wheat productivity is increasingly threatened by impact of climate change, which significantly affected agricultural output (Rana et al., 2024). The rising global temperature poses a major challenge to wheat cultivation (Fernie et al., 2022; Anonymous, 2022). Intergovernmental Panel on Climate Change (IPCC) predicts a global temperature increase of 0.3°C per decade, potentially reaching 1°C above current levels by 2025 and 3°C by 2100 (Singh and Dwivedi, 2015). As the world population is growing at an exponential rate, meeting the growing demand for wheat products necessitates more concentrated efforts to improve the production and productivity of wheat in a changing climate scenario. It is estimated that wheat production must be increased by 60% to meet the demand of the growing population (Narayanan, 2018). The cultivation of wheat in major wheat-growing regions is being impacted by heat waves (Mondal et al., 2016; Xu et al., 2022). As per the global climate models, the mean ambient temperature is predicted to increase by 1.5°C within the next two decades (Masson-Delmotte et al., 2021). In India, high-temperature stress during the grain-filling stage is critical factor reducing wheat yield in major wheat-growing regions (Asseng et al., 2015; Ullah et al., 2022, Rehman et al., 2021). Delayed sowing beyond the third week of November has been reported to result in a yield loss of 35–45 kg ha^{-1} day^{-1}, with an annual loss of up to 10 million tonnes (Reynolds et al., 1994). Heat stress disrupts vital physiological and biochemical processes in wheat, impairing metabolic functions at all developmental stages and ultimately reducing grain yield and quality (Al-Ashkar et al., 2020; Riaz et al., 2021; Fernie et al., 2022, Prasad et al., 2011; Pradhan et al., 2012; Perdomo et al., 2015, 2017). Existing popular wheat varieties grown in Indo-Gangetic plains are largely sensitive to heat stress, emphasizing the need for genotypes capable of withstanding high temperatures during the reproductive and grain-filling stages. Given these challenges, the development of heat-tolerant wheat genotypes has become a priority of wheat breeding programs. Screening and evaluation of wheat genotypes using stress tolerance indices is crucial for identifying heat-tolerant varieties which could sustain productivity under high-temperature conditions. The present study aimed to evaluate 205 wheat genotypes (including five checks) to identify heat-tolerant genotypes using various stress tolerance indices. This effort contributes to the development of wheat varieties better equipped to cope with heat stress, ensuring sustainable production in changing climatic conditions.

2. MATERIALS AND METHODS

The present study was conducted during *rabi* seasons (November to April of 2022–2023 and 2023–2024 at Research Area of the Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana, India to evaluate 205 wheat genotypes, including five checks in augmented design under normal (timely sown) and heat stress (late sown) conditions. Geographically, the field experimental site is located at a latitude of 29.1503° N, a longitude of 75.7056° E and an altitude of 215.2 m above mean sea level within the sub-tropical region of the North-Western Plains Zone (NWPZ) of India. Experimental area was divided into 8 blocks; each block comprised of 25 test genotypes and 5 checks. Each plot comprised of one genotype with three rows of 2 m length. Further, row -to-row and plant-to-plant distance was kept at 20 cm and 10 cm respectively. The recommended package of practices for wheat cultivation were followed to raise good quality crop. Observations for grain yield $plot^{-1}$ was recorded for each genotype for both environmental conditions. Corresponding pooled mean values for timely and late sown environments of two seasons (*Rabi,* 2022–23 and *Rabi,* 2023–24) were used to calculate various stress indices mentioned in table 1.

3. RESULTS AND DISCUSSION

The present study aimed to evaluate the heat tolerance of bread wheat (*Triticum aestivum* L. em. Thell) genotypes by analyzing their performance under normal (timely sown) and heat stress (late sown) conditions using various stress tolerance indices including heat susceptibility index (HSI), stress tolerance index (STI), mean productivity (MP), tolerance (TOL), yield stability index (YSI) and yield index (YI). The results revealed significant variability among the genotypes for grain yield and heat tolerance, highlighting the differential response of wheat genotypes to high-

Table 1: Various stress indices calculated

Sl. No.	Parameter	Formula	Suggested by	Interpretation
1.	Reduction	X_H-X_N/ X_H×100	-	The lower value of reduction for a genotype indicates better performance under heat stress
2.	Heat susceptibility index (HSI)	(1 – X_H/X_N)/1-Y_H/Y_N	Fischer and Maurer (1978)	The lower value of HSI for a genotype indicates heat stress tolerance and the higher values indicates heat stress susceptibility by a genotype
3.	Mean productivity (MP)	(X_H+X_N)/2	Hossain et al. (1990)	Higher value of MP is the indicator of genotypes having superior performance under both the normal and heat stress environments
4.	Stress tolerance (TOL)	X_H-X_N	Hossain et al. (1990)	The negative (lowest) value of TOL indicates higher tolerance of a genotype to heat stress
5.	Stress tolerance index (STI)	X_N×X_H/(Y_N)2	Fernandez (1992)	Maximum STI value is the better indicator of the superior performance of genotype under both the normal and heat stress environment
6.	Yield stability index (YSI)	X_N/X_H	Bouslama and Schapaugh (1984)	Maximum TSI values are the better indication of the superior performance of genotypes under heat stress environment
7.	Yield index (YI)	X_H/Y_H	Gavuzzi et al. (1997)	The higher YI value for a genotype corresponds to higher heat stress tolerance

XH: Mean grain yield of individual genotype under heat stress i.e. late sown conditions; XN: Mean grain yield of individual genotype under non stress i.e. timely sown conditions; YH: Mean grain yield of all genotypes under heat stress i.e. late sown conditions; YN: Mean grain yield of all genotype under non stress i.e. timely sown conditions

temperature stress. These indices not only facilitated the identification of heat-tolerant genotypes but also provided insights into the underlying mechanisms contributing to heat stress resilience.

3.1. Mean grain yield plot^{-1} and stress indices

3.1.1. Grain yield plot^{-1}

The grain yield plot^{-1} of various wheat genotypes under timely sown (normal) conditions ranged from 340.5 g to 925.0 g, with a mean value of 546.42 g. The lowest grain yield was observed in NP 710 (340.5 g), followed by DL 788-2 (385.5 g), VL 401 (393.0 g), NP 52 (394.5 g) and MANDAKINI (397.0 g), while the highest grain yield was observed in K 7410 (925.0 g). Under late sown (stress) conditions, the grain yield plot^{-1} ranged from 314.5 g to 674.0 g, with a mean value of 458.56 g. The lowest grain yield in stress conditions was recorded in NP 710 (314.5 g), followed by K 8027 (327.0 g), NP 770 (328.0 g), Raj 1114 (336.0 g), and HP 1493 (337.5 g) with the highest grain yield also observed in K 7410 (674.0 g) (Table 2).

3.1.2. Reduction in grain yield plot^{-1}

The effect of heat stress on grain yield of tested wheat genotypes was clearly illustrated by the calculation of % decline. The reduction in mean grain yield under heat stress conditions highlights that elevated temperature accelerate wheat life cycle, limiting optimal development of yield attributing traits and ultimately reducing the grain yield. The relative per cent decrease in grain yield of various wheat genotypes ranged from 2.23 to 38.13% under heat stress (Table 2).

Table 2: Descriptive statistics of grain yield and stress tolerance indices in wheat genotypes under normal and heat stress environments

Sl. No.	Parameter	Minimum	Maximum	Mean
1.	Grain yield plot^{-1} (g) (Normal)	340.5	925	546.42
2.	Grain yield plot^{-1} (g) (Stress)	314.5	674	458.56
3.	Reduction	2.23	38.13	15.72
4.	Heat susceptibility index (HSI)	0.14	2.34	0.96
5.	Mean productivity (MP)	327.5	799.5	502.49
6.	Stress tolerance (TOL)	11	255	87.87
7.	Stress tolerance index (STI)	0.34	1.99	0.81
8.	Yield stability index (YSI)	0.62	0.98	0.84
9.	Yield index (YI)	0.67	1.44	0.98

3.1.3. Heat susceptibility index (HSI)

The HSI of tested wheat genotypes ranged from 0.14 to 2.34 (Table 2). The lowest heat susceptibility index was observed in Raj 2184 (0.14) followed by VL 421 (0.14), HD 2824 (0.16), UP 215 (0.17) and HD 2733 (0.18) that indicated heat stress tolerance. Highest HSI was observed in HUW 12 (2.34) which indicates heat stress susceptibility of the genotype.

3.1.4. Mean productivity (MP)

The mean productivity of various wheat genotypes ranged from 327.5 to 799.5 with mean value of 502.49 (Table 2). The lowest mean productivity was observed in NP 710 (327.50) followed by MANDAKINI (368.00), VL 401 (370.50), DL 788-2 and K 8027 (376.00). Highest mean productivity was observed in K 7410 (799.50) that represents superior performance under both the normal and heat stress environment.

3.1.5. Stress tolerance (TOL)

Stress tolerance of various wheat genotypes ranged from 11 to 255 with mean value of 87.87 (Table 2). The lowest stress tolerance was observed in VL 421 (11.00) followed by Raj 2184 (12.00), HD 2824 (12.50), UP 215 (14.50) and HD 27.33 (15.00). Highest stress tolerance was observed in NIAW 301 (255.00).

3.1.6. Stress tolerance index (STI)

Stress tolerance index of various wheat genotypes ranged from 0.34 to 1.99 with mean value of 0.81 (Table 2). The lowest stress tolerance index was observed in NP 710 (0.34) followed by MANDAKINI (0.43), VL 401 (0.44), DL 788-2 (0.44) and K 8027 (0.44). Highest stress tolerance index was observed in K 7410 (1.99). Maximum STI value is the better indicator of the superior performance of genotype under both the normal and heat stress environment.

3.1.7. Yield stability index (YSI)

Yield stability index of various wheat genotypes ranged from 0.62 to 0.98 with mean value of 0.84 (Table 2). The lowest yield stability index was observed in HUW 12 (0.62) followed by HUW 55 (0.64), K 88 (0.67), NIAW 301 (0.68) and HD 2851 (0.68). Highest yield stability index was observed in Raj 2184 (0.98). Maximum YSI values are the better indication of the superior performance of genotypes under heat stress environment.

3.1.8. Yield index (YI)

Yield index of various wheat genotypes ranged from 0.67 to 1.44 with mean value of 0.98 (Table 2). The lowest yield index was observed in NP 710 (0.67) followed by K 8027 (0.70), NP 770 (0.70), Raj 1114 (0.72) and HP 1493 (0.72). Highest yield index was observed in K 7410 (1.44). The higher YI value for a genotype corresponds to higher heat stress tolerance.

Similarly, Lamba et al. (2023) found that genotypes namely HD 2967, WH 1249, HI 1617, WH 1202, WH 1021 and WH 1142 were heat tolerant and high yielding genotypes based on stress tolerance index, mean productivity, geometric mean, harmonic mean and mean relative performance. Thapa et al. (2020) revealed that 9 genotypes (G51, G64, G71, G114, G119, G134, G139, G148 and G150) were heat tolerant and 12 genotypes (G1, G3, G7, G27, G38, G40, G77, G107, G136, G160, G171 and G187) were highly heat susceptible based on six stress tolerance indices viz. heat susceptibility index, mean productivity, tolerance, stress tolerance index, trait stability index and trait index. Khan and Kabir (2014) used seven selection indices including mean productivity, geometric mean productivity, tolerance, yield index, yield stability index, stress tolerance index and stress susceptibility index to reveal that the genotypes G-05 and G-22 were found to be the best genotypes with relatively high yield and suitable for both optimum and late heat stressed conditions. Khajuri et al. (2016) used heat susceptibility index value to identify a total of thirteen genotypes as tolerant to heat. Vedi et al. (2024) found that heat susceptibility index value for grain filling duration and canopy temperature ranged from 0.57 to 1.35 with a mean value of 1.00 and 0.58–1.29 with a mean value of 1.005, respectively. Two genotypes (WH730 and HUW468) showed tolerance to heat in all traits.

3.2. Correlation between grain yield and stress tolerance indices

The correlation coefficient between grain yield under normal & late sown conditions; and heat tolerance indicators were calculated to estimate the most appropriate stress tolerant criterion (Table 3, Figure 1). On the basis of correlation

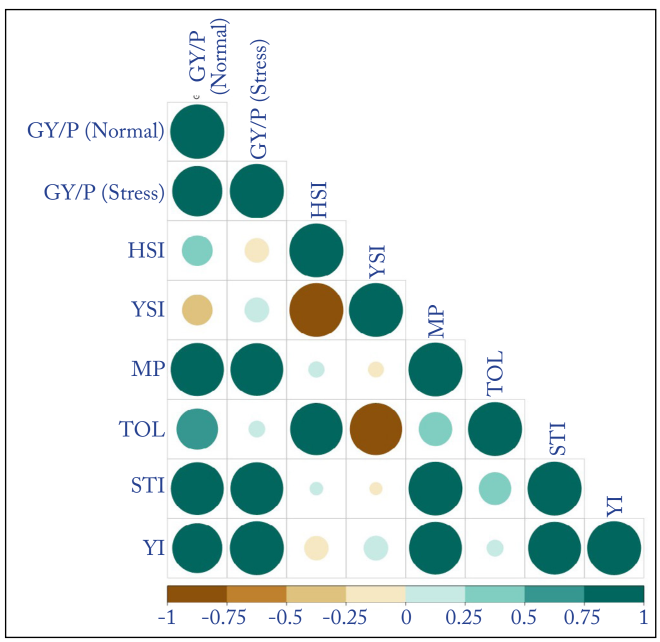

Figure 1: Correlogram representing association among various traits

Table 3: Correlation coefficient between grain yield (Normal and stress) of wheat genotypes and various stress tolerance indices

Character	GY/P (Normal)	GY/P (Stress)	HSI	YSI	MP	TOL	STI	YI
GY/P (Normal)	1							
GY/P (Stress)	0.859**	1						
HSI	0.320**	-0.203**	1					
YSI	-0.316**	0.206**	-0.099**	1				
MP	0.971**	0.956**	0.089	-0.085	1			
TOL	0.591**	0.095	0.942**	-0.940**	0.382**	1		
STI	0.960**	0.958**	0.062	-0.058	0.994**	0.358	1	
YI	0.859**	1.000**	-0.201**	0.205**	0.956**	0.096	0.958**	1

GY/P: Grain yield plot^{-1} (g); HSI: Heat susceptibility index; MP: Mean productivity; TOL: Stress tolerance; STI: Stress tolerance index; YSI: Yield stability index; YI: Yield index; *, ** Significant at (p=0.05) and (p=0.01) levels of probability, respectively

study, it was found that grain yield plot^{-1} in normal condition exhibited positive and highly significant association with grain yield plot^{-1} in stress condition that indicated that they may be used to identify high-yielding genotypes under both conditions. Furthermore, GY/P (normal) exhibited positive and highly significant association with all heat stress indices i.e. HSI, MP, TOL, STI, YI except YSI as it exhibited negative and highly significant association. Therefore, selection based on these indices will enhance grain yield under non stressed conditions but decrease under stress conditions. On the other hand, grain yield plot^{-1} under stress condition exhibited positive and highly significant association with YSI, MP, STI, YI while negative and highly significant association with HSI. A similar pattern of correlation and selection criteria for heat tolerance in durum wheat was reported by Talebi et al. (2008), Thapa et al. (2020) and Lamba et al. (2023).

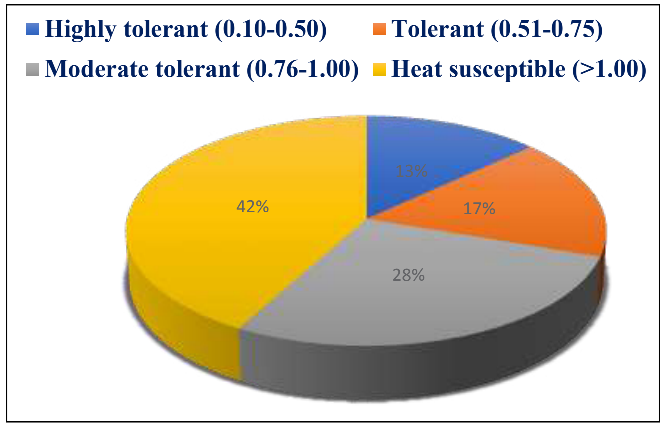

Figure 2: Pie chart depicting categorization of 205 bread wheat genotypes into four classes on the basis of heat susceptibility index

3.3. Response of 205 bread wheat genotypes on the basis of heat susceptibility index (HSI)

Out of tested 205 bread wheat genotypes, 27 (13%) bread wheat genotypes were found highly tolerant, 35 (17%) were found tolerant, 57 (28%) were found moderately tolerant whereas 86 (42%) were found heat susceptible (Table 4; Figure 2). The HSI of various wheat genotypes ranged from 0.14 to 2.34 (Table 2).

Table 4 represents that 205 bread wheat genotypes were categorized into four categories based on their Heat Susceptibility Index (HSI). Twenty-seven genotypes were grouped into highly tolerant category. These genotypes show minimal yield reduction under heat stress, indicating excellent heat tolerance. Thirty-five genotypes were grouped into tolerant category. These genotypes demonstrated good heat tolerance with moderate yield reductions under stress conditions. They could be used in environments prone to mild heat stress. Fifty-seven genotypes were grouped into moderate tolerant category. These genotypes exhibited moderate heat tolerance, with a noticeable but manageable decline in yield under stress conditions. They might require additional support (such as agronomic management) in severe heat stress conditions. Eighty-six genotypes were found to be susceptible. These genotypes are highly sensitive to heat stress, showing significant yield reductions under stress conditions. They are not recommended for heat-prone regions unless improved through breeding. Highly tolerant and tolerant genotypes should be prioritized for breeding programs aimed at improving heat tolerance in wheat. Heat-susceptible genotypes can serve as contrasting materials in physiological, molecular, and biochemical studies of heat stress. This classification provides a useful framework for selecting suitable genotypes for cultivation in heat-stressed environments or for breeding programs targeting heat tolerance in wheat.

In the present study, out of the top 10 heat susceptible wheat genotypes, RS-31-1 was the most susceptible

Table 4: Classification/ Response of 205 bread wheat genotypes against heat stress based on heat susceptibility index (HSI)

Response to heat stress (HSI value)	No. of genotypes	Identified genotypes
Highly tolerant (0.10-0.50)	27	Raj 2184, VL 421, HD 2824, UP 215, HD 2733, K 9644, RS 31-1, HD 2833, HPW 147, HD 2307, NP 771, HP 1761, Raj 3077, UP 1109, HD 2402, WL 711, UP 262, PBW 509, DL 788-2, MLKS 11, WH 147, KSML 3, NP 710, NW 1067, PBW 12, NP 52, HI 1454
Tolerant (0.51-0.75)	35	K 9351, K 816, HD 2135, PV 18, PBW 154, SKW 196, NP 832, UP 368, PBW 120, WH 283, LOK 1, NI 5439, VL 738, WL 410, HW 517, VL 404, HD 2327, HD 2278, WG 377, VL 802, J 405, NP 836, VL 829, NIAW 34, WH 157, VL 832, VL 401, WH 542, RSP 561, SHARBATI SONORA, HP 1744, K 9533, HD 2501, HI 1418, UP 2382
Moderate tolerant (0.76-1.00)	57	PBW 54, DBW 14, HD 2236, NP 745, HI 977, MACS 2496, PBW 65, HPW 89, NP 792, K 8962, PBW 443, UP 2425, HD 2864, PBW 396, NP 120, WH 1124, HW 741, NP 824, NP 825, NP 809, UP 2565, K 9423, NP 111, PBW 226, HD 2204, K 78, HD 3059, NP 823, J 1-7, PBN 142, HW 2004, NP 165, HP 1731, NP 721, MANDAKINI, VL 804, HS 86, UP 2003, HI 1612, HD 2985, K 9162, NP 12, HS 1138-6-4, K 8434, K 7903, NP 715, C 306, PBW 1Z, NK 9006, PBW 138, HD 2177, PBW 373, SONORA 64, HD 1982, J 24, WH 771, HS 420
Heat susceptible (>1.00)	86	HD 2643, JWS 17, NI 345, HW 657, S 331, NP 799, HUW 206, K 65, SAFED LERMA, UTKALIKA, NP 101, HD 2009, NP 839, HS 277, PBN 51, HI 784, NP 114, WL 2265, DBW 222, WG 357, HD 2781, Raj 4037, KRL 19, HUW 213, UP 115, NP 4, HS 207, NP 718, NW 1014, HD 2380, UP 2338, HS 295, SONALIKA, WH 1025, HD 1941, HP 1102, HS 1097-17, NP 761, HI 1500, KRLI 4, HS 375, DBW 16, TAWA 267, HD 3086, PBW 343, WL 1562, WH 1105, HD 2285, PBW 175, HS 365, RIDLEY, HYB 65, K 53, VL 616, K 8027, Raj 821, HW 2045, HD 2281, NW 2036, NP 890, NARMADA 4, Raj 1114, Raj 1482, K 8020, HD 2687, HDR 77, HPW 184, UP 2121, NP 770, HUW 37, HD 2189, HY 5, NP 818, K 7410, Raj 1972, HD 1981, KSHIPRA, NARMADA 112, HD 2270, HP 1493, HY 12, HD 2851, NIAW 301, K 88, HUW 55, HUW 12

genotype as it had the lowest value of grain yield under heat stress environment (Table 6). However, out of the top 10 Heat tolerant wheat genotypes, genotype Raj 2184 and UP 215 showed high yield under heat stress environment (Table 5). These analyses were based on the study of certain stress indices, such as HSI, MP, STI and TI. From the above analysis, it may be concluded that most of the wheat genotypes are largely tolerant to heat stress and only a smaller fraction of genotypes in the germplasm show susceptible to heat stress. Our study is in conformity with

Table 5: Top 10 heat tolerant wheat genotypes based on HSI

Sl. No.	Genotype	GY/P (Normal)	GY/P (Stress)	HSI	MP	TOL	STI	YSI	YI
1.	Raj 2184	538.00	526.00	0.14	532.00	12.00	0.90	0.98	1.12
2.	VL 421	487.50	476.50	0.14	482.00	11.00	0.74	0.98	1.02
3.	HD 2824	492.00	479.50	0.16	485.75	12.50	0.75	0.97	1.02
4.	UP 215	538.50	524.00	0.17	531.25	14.50	0.90	0.97	1.12
5.	HD 2733	499.00	484.00	0.18	491.50	15.00	0.77	0.97	1.03
6.	K 9644	513.50	496.50	0.20	505.00	17.00	0.81	0.97	1.06
7.	RS 31-1	406.50	391.00	0.23	398.75	15.50	0.51	0.96	0.83
8.	HD 2833	507.00	486.00	0.25	496.50	21.00	0.79	0.96	1.04
9.	HPW 147	510.00	486.00	0.29	498.00	24.00	0.79	0.95	1.04
10.	HD 2307	473.50	451.00	0.29	462.25	22.50	0.68	0.95	0.96

GY/P: Grain yield plot^{-1} (g); HSI: Heat susceptibility index; MP: Mean productivity; TOL: Stress tolerance; STI: Stress tolerance index; YSI: Yield stability index; YI: Yield index

Table 6: Top 10 heat susceptible wheat genotypes based on HSI

Sl. No.	Genotype	GY/P (Normal)	GY/P (Stress)	HSI	MP	TOL	STI	YSI	YI
1.	KSHIPRA	729.00	513.00	1.82	621.00	216.00	1.19	0.70	1.09
2.	NARMADA 112	509.00	355.00	1.86	432.00	154.00	0.58	0.70	0.76
3.	HD 2270	577.50	402.00	1.86	489.75	175.50	0.74	0.70	0.86
4.	HP 1493	487.00	337.50	1.88	412.25	149.50	0.52	0.69	0.72
5.	HY 12	640.50	443.00	1.89	541.75	197.50	0.90	0.69	0.94
6.	HD 2851	621.50	425.00	1.94	523.25	196.50	0.84	0.68	0.91
7.	NIAW 301	785.00	530.00	1.99	657.50	255.00	1.33	0.68	1.13
8.	K 88	645.50	434.50	2.01	540.00	211.00	0.89	0.67	0.93
9.	HUW 55	667.50	424.00	2.24	545.75	243.50	0.90	0.64	0.90
10.	HUW 12	608.50	376.50	2.34	492.50	232.00	0.73	0.62	0.80

GY/P: Grain yield plot^{-1} (g); HSI: Heat susceptibility index; MP: Mean productivity; TOL: Stress tolerance; STI: Stress tolerance index; YSI: Yield stability index; YI: Yield index

previously reports such as Okechukwu et al. (2016) found that the relative heat tolerance of the genotypes ranged from -33.69% to -77.95% in late season 1 vs. normal season 1 and -65.28% to -95.83% in late season 2 vs. normal season 2. Khan and Kabir (2014) used seven selection indices including mean productivity (MP), geometric mean productivity (GMP), tolerance (TOL), yield index (YI), yield stability index (YSI), stress tolerance index (STI) and stress susceptibility index (SSI) to reveal that the genotypes G-05 and G-22 were found to be the best genotypes with relatively high yield and suitable for both optimum and late heat stressed conditions. The indices SSI, YSI and TOL could be useful parameters in discriminating the tolerant genotypes (G-12, G-13, and G-14). Khajuri et al. (2016) used heat susceptibility index value to identify a total of thirteen genotypes as tolerant to heat. Thapa et al. (2020) revealed that 9 genotypes (G51, G64, G71, G114, G119, G134, G139, G148 and G150) were heat tolerant and 12 genotypes (G1, G3, G7, G27, G38, G40, G77, G107, G136, G160, G171 and G187) were highly heat susceptible based on six stress tolerance indices viz. heat susceptibility index, mean productivity, tolerance, stress tolerance index, trait stability index and trait index.

Yadav et al. (2020) categorized wheat genotypes based on HSI values into three groups tolerant (HSI=1.0) and intermediate (HSI=0.5–1.0), DBW16, DBW14 and DBW39 showed least values of HSI, indicating that they were heat tolerant. Tiwari et al. (2012) categorized genotypes based on HSI as: heat tolerant (HSI<0.70), moderately heat tolerant (HSI >0.70–1.20– 1.70). Shehrawat et al. (2020) reported significant variance among accessions for the HSI of all the traits recorded; HSI for grain yield ranged from 0.05 to 1.73, which is almost exactly in concurrence of the results of present research. Dhyani et al. (2013) and Kumar et al. (2021) also carried out the similar experiments to screen heat tolerant genotypes of bread wheat.

4. CONCLUSION

Genotypes such as Raj 2184, VL 421, HD 2824, UP 215, HD 2733, K 9644, RS 31-1, HD 2833, HPW 147 and HD 2307 exhibited promising strong performance under terminal heat stress. Hence, these genotypes could serve as promising candidates for breeding programs.

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