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Evaluation and Identification of thermotolerant genotypes in bread wheat

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Abstract
Heat stress is one of the major limitations in wheat (*Triticum aestivum* L.) productivity in arid, semiarid, tropical and semi tropical regions of world. Wheat is grown as winter cereal crop in subtropical countries like India. The crop experiences chronic high temperature at most of phenological stages of growth. The present study was undertaken to identify heat tolerant wheat genotypes based on their response for days to flowering and days to maturity in normal, late and very late sown condition. A set of 20 wheat genotypes was evaluated with split plot design under normal, late and very late sowing conditions by altering sowing dates. Data analysis revealed that sowing time and genotype has significant effect on traits like days to flowering and days to maturity. Based on the time taken by the genotypes to flower and mature under late sowing and very late sowing conditions, six genotypes showing heat tolerance were found to be resistant. Heat susceptibility index value was used to identify genotypes as tolerant to heat for various traits. The genotypes identified as heat tolerant would form an important resource for the development of high-yielding varieties under heat stress.

Keywords: Wheat, heat stress, heat susceptibility index, genotypes, thermotolerance

Introduction
Wheat (*Triticum aestivum* L.) is a self-pollinating annual plant belonging to the family Poaceae (grasses) and genus Triticum. It is one of the most important cereal crops for the majority of world's population as it is used as a staple food of about two billion people (i.e. approximately 40% of world population). India has largest area (30.60 m ha) under wheat cultivation in the world followed by China (24 m ha). The crop is cultivated in Maharashtra during 2017-18 was on 1.07 million ha area with production of 1.67 million tonnes and with average productivity of 15.58 q ha^{-1}. Productivity of Maharashtra (15.58 q ha^{-1}) is half that of India (32.16 q ha^{-1}) (Anonymous, 2018) [1].

It has been reported that seed germination and seedling emergence in wheat are adversely affected by exposure to heat stress or high temperature (Tewolde *et al.*, 2006) [8]. High temperarture induces early flowering and reduces days required for maturity which lowers grain feeling period of crop and in turn reduces crop yield (Amrawat *et al.*,2013 [2] Heat stress changed the morphology and reduced the grain size, plant height, grain growth duration, kernel number and kernel weight. Present trend in India and neighboring countries indicate that the "Cool period" for wheat crop is shrinking which indicate the threat of increasing terminal heat stress (Joshi *et al*., 2007) [3]. Kaur *et al*., (2009) [4] stated that, heat tolerance as measured by heat susceptibility index reflects the stability of performance of genotypes under non stress and heat stress environments and does not take into account the actual yield obtained under heat stress. A heat tolerant genotype can have a low mean yield and consequently will be of no commercial value but will have a good academic value, whereas heat susceptible but exceptionally higher yielding genotype can still give better yield under stress environment. Thus, the genotypes identified on the basis of both these criteria could be of immense use for further exploitation in breeding programme.

The present study was aimed at identifying heat tolerant genotypes on the basis of heat susceptibility index (HSI) and performance under late and very late sowing heat stressed conditions for days to flowering and days to maturity.

Materials and Methods
The experimental material for the study consisted of 20 genotypes of wheat obtained from Wheat Research Station, Niphad, MPKV Rahuri, Maharashtra. The present investigation was conducted at Botany Farm, College of Agriculture, Pune during Rabi season, 2018-19. The experiment was conducted in a split plot design with three staggered sowing as (D1) normal, (D2) late and (D3) very late sown condition by altering sowing dates and three replications.

Each genotype was planted in three rows, each of 2.5 meter length with a spacing of 22.5 cm between rows and 10 cm between plants. All agronomic practices recommended for the normal wheat crop were followed. The phenotypic data for days to flowering (DTF) and days to maturity (DTM) was recorded for each genotype in each replication. DTF was recorded as the number of days required for half the length of spikes to emerge out in 50% of plants in a plot. Similarly days to maturity was recorded as the number of days required for 50% of a plot to become physiologically mature as evident from yellowing of plants.

Statistical analysis

The analysis of variance (ANOVA) was carried out to study the effect of date of sowings and genotypes on the days to flowering and days to maturity under normal, late and very late sowing. Two way tables were obtained to observe variations in days to 50% flowering and days to maturity over dates of sowing and among genotypes.

Heat Susceptibility Index (HSI) Heat susceptibility index (HSI) was used to evaluate the effect of heat stress on days to flowering and days to maturity. The formula used for HSI calculation, taken from Paliwal *et al*. (2012) [6], is given below:

HSI of X= [(1- Xheat stress/ Xcontrol)/D]

Where

X represents DTF and DTM

Xheat stress represents phenotypic values of individual genotypes for DTF and DTM under late sowing

Xcontrol represents phenotypic values of individual genotypes for DTF and DTM under normal sowing

D (stress intensity) = (1- Yheat stress/ Ycontrol)

Yheat stress= Mean of Xheat stress of all genotypes

Ycontrol= Mean of Xcontrol of all genotypes

Results and discussion

The data on 20 wheat genotypes was evaluated for days to flowering (DTF) and days to maturity (DTM) under three regimes of sowing i.e normal, late and very late sowing.

Days to 50 percent flowering

Highly significant differences were observed for days to 50 percent flowering amongst the genotypes, different sowing dates and interaction between sowing dates and genotypes.

Data indicated that duration required for days to 50 percent flowering (Table 1) were significantly reduced under D3 (57 days) and D2 (63 days) as compared to D1 (69 days). Days to 50 percent flowering was reduced due to high temperature stress induced by late sowing and very late sowing. Maximum days required for 50 percent flowering was observed in NIAW 3583 (71 days) and NIAW 3578 (70 days). Significantly minimum days required for 50 percent flowering was in genotype NIAW 3170 (55 days) followed by NIAW 4013, NIAW 3927 (58 days), NIAW 4033(59 days), NIAW 3898 (60 days), NIAW 3977 and NIAW 3975(61 days) indicating their earliness to flowering.

All the wheat genotypes showed reduction in days to 50 percent flowering due to high temperature stress induced by late sowing but genotypes NIAW 3583 and NIAW3578 showed minimum reduction of 4 days for late sown and 8 days for very late sown condition. While maximum reduction was noticed in NIAW 3170 for 9 days in late sown and 14 days for very late sown condition. The late sown and very late sown crop required relatively less days i.e. 63 and 57 days respectively. It indicates that high temperature stress reduces the days (7.08) for flowering in wheat. Similar results were reported by Khan *et al.,* (2007) [5] who stated that all genotypes of wheat took more days to heading under normal sowing (17^{th} November) as compared to those of late sowing (20^{th} December). Kaur *et al.,* (2009) [4] also reported that numbers of days required for sowing to anthesis were less under late sown wheat as compared to normal sown.

Table 1: Effect of Date of sowing, genotypes and their interaction on days for 50 percent flowering.

Days for 50 percent flowering				
	Date of sowing			
Genotypes	**D 1**	**D 2**	**D 3**	**Mean**
NIAW 3977	67	61	54	61
NIAW 3583	75	71	67	71
NIAW 3771	72	67	62	67
NIAW 3895	72	67	62	67
NIAW 3927	65	57	52	58
NIAW 3991	70	65	60	65
NIAW 3983	68	62	56	62
NIAW 3980	68	62	56	62
NIAW 4033	66	58	53	59
NIAW 3942	68	63	57	63
NIAW 3578	74	70	66	70
NIAW 3170	63	54	49	55
NIAW 3898	67	61	54	60
NIAW3908	70	64	59	64
NETRAVATI	70	64	58	64
NIAW 34	70	64	58	64
Phule Samadhan	68	63	57	63
NIAW 4013	65	57	52	58
NIAW 3947	68	62	56	62
NIAW 3975	67	61	55	61
Mean	69	63	57	63
	Result	SE (m) ±	CD at 5 percent	
Date of sowing(D)	SIG	0.07	0.29	
Genotypes(G)	SIG	0.28	0.78	
D X G	SIG	0.48	1.36	

Days to maturity

Days to maturity were reduced under D3 condition than D1 and D2. Significantly maximum days were required for maturity in D1 (113 days) compared to D2 (106 days) and D3 (101 days).

Table 2: Effect of Date of sowing, Genotypes and their interaction on days for maturity.

Days for maturity				
	Date of sowing			
Genotypes	**D1 (24^{th} Dec.2018)**	**D2 (4^{th} Jan.2019)**	**D3 (14^{th} Jan.2019)**	**Mean**
NIAW 3977	108	102	99	103
NIAW 3583	135	129	106	123
NIAW 3771	119	111	105	111
NIAW 3895	120	113	105	113
NIAW 3927	105	100	97	101

NIAW 3991	118	110	104	111
NIAW 3983	112	104	102	106
NIAW 3980	112	102	101	105
NIAW 4033	106	101	97	101
NIAW 3942	114	104	102	107
NIAW 3578	123	114	106	114
NIAW 3170	104	99	95	99
NIAW 3898	106	101	97	102
NIAW3908	115	109	104	109
NETRAVATI	115	109	103	109
NIAW 34	114	107	103	108
Phule Samadhan	114	107	102	108
NIAW 4013	105	100	96	100
NIAW 3947	110	102	100	104
NIAW 3975	109	102	100	104
Mean	113	106	101	107
	Result	SE (m) ±	CD at 5%	
Date of sowing(D)	SIG	0.31	1.21	
Genotypes(G)	SIG	0.33	0.93	
D X G	SIG	0.57	1.61	

High temperature stress induced by late sowing caused reduction by 6 days for days to maturity for D2 and 11 days for D3 as compared to D1. The maximum days required for maturity was recorded by NIAW 3583 (123 days) indicating long growth cycle followed bygenotypes NIAW 3583, NIAW 3578, NIAW 3895, NIAW 3771 and NIAW 3991. The genotype NIAW 3170 (99 days) required minimum days for maturity.

In the present investigation the days required for maturity was reduced for all genotypes under D3 (very late sowing) condition as compared to that of D1 (normal sown) and D2 (late sown) due to increase in temperature. Similar results were reported by Parry and Swaminathan (1992) [7], who reported that an increase of 0.5°C temperature resulted in decrease in the duration of wheat crop by 7 days. It would thus be seen that sowing date influence was of greater order under 3rd sown condition as compared to 1st and 2nd sowing conditions.

Heat susceptibility index

HSI was calculated twice, first over normal sown and late sown condition and second over normal sown and very late sown condition for days to 50% flowing and days to maturity.

In this experiment, for days to 50% flowering over D1 and D2 condition, the highest heat susceptibility index value was recorded by the genotype NIAW3170 (1.60) followed by NIAW 4013(1.37), NIAW 3927 (1.36) and NIAW 4033 (1.35). This showed that these genotypes were susceptible. The lower values were recorded by the genotypes NIAW 3578 (0.60), NIAW 3583 (0.64), NIAW 3895 (0.72) and NIAW 3771 (0.78) indicated their tolerance to late sown condition. Higher values indicate susceptibility whereas lower values show resistance of genotypes to changing temperature.

HSI values over D1 and D3 condition was higher for genotypes NIAW 3170 (1.31), NIAW 3927 (1.17), NIAW 4033 (1.16) and NIAW 3898 (1.12). While, lower HSI was observed for genotypes NIAW 3583 (0.63), NIAW 3578 (0.64) and NIAW 3895 (0.79) which indicated their tolerance for very late sown condition.

HSI for days to maturity varied among the genotypes. Over D1-D2 condition, higher HSI was observed in genotypes *viz*; NIAW 4033 (4.77), NIAW 3898 (4.67), NIAW3170 (4.65), NIAW 4013 (4.63) and NIAW 3927 (4.43) and was more than the checks NIAW 34 (2.47) and Phule Samadhan (2.25). Lower HSI was observed in genotypes NIAW 3583 (0.82), NIAW 3895 (1.27), NIAW 3983 (1.37), NIAW 3980 (1.62) and NIAW 3578 (1.65).

For D1-D3 condition, genotypes NIAW 4013 (1.97), NIAW 3927 (1.24), NIAW 4033 (1.13), NIAW 3170 (1.09) and NIAW 3975 (1.16) showed greater HSI than checks NIAW 34 (0.93) and Phule Samadhan (0.93). While genotypes NIAW 3583 (0.69), NIAW 3991 (0.72), NIAW 3578 (0.73), Netravati (0.75) and NIAW 3983 (0.76) had less HSI. As like present experiment, similar results were obtained in experiment conducted by Khujaria *et al.,* (2016) to identify heat tolerant wheat genotypes on their response for days to flowering and days to maturity. The HSI for days to maturity ranged from 0.72 to 2.14. HSI estimates for 51 genotypes showed both resistant and tolerant genotypes.

Table 3: Heat susceptibility index

Sr. No.	Genotype	Days for 50% flowering		Days for Maturity	
		D1-D2	D1-D3	D1-D2	D1-D3
1	NIAW 3977	0.94	1.09	3.16	0.86
2	NIAW 3583	0.64	0.63	0.82	0.69
3	NIAW 3771	0.78	0.82	2.88	0.77
4	NIAW 3895	0.72	0.79	1.21	0.75
5	NIAW 3927	1.36	1.17	4.43	1.24
6	NIAW 3991	0.79	0.84	3.06	0.72
7	NIAW 3983	0.98	1.03	1.37	0.76
8	NIAW 3980	0.93	1.01	1.62	0.87
9	NIAW 4033	1.35	1.16	4.77	1.13
10	NIAW 3942	0.81	0.98	1.72	0.91
11	NIAW 3578	0.60	0.64	1.65	0.73
12	NIAW 3170	1.60	1.31	4.66	1.09
13	NIAW 3898	1.00	1.12	4.67	0.77
14	NIAW3908	0.95	0.92	3.20	0.92
15	NETRAVATI	0.90	0.96	3.29	0.75
16	NIAW 34	0.96	0.99	2.47	0.93
17	Phule Samadhan	0.81	0.95	2.25	0.93
18	NIAW 4013	1.37	1.18	4.63	1.97
19	NIAW 3947	0.98	1.07	2.35	0.82
20	NIAW 3975	0.99	1.08	3.87	1.06

Identification of heat stress tolerant genotypes

The performances under late sowing condition revealed significant effects of heat stress on the both traits. A total of 6 genotypes namely, NIAW 3583, NIAW 3578, NIAW 3895, NIAW 3771, NIAW 3991, NIAW 34 suggesting their ability to withstand heat stress.

Heat Susceptibility Index (HSI) estimates for all genotypes showed both resistant and tolerant genotypes. For DTF, lowest HSI values obtained for genotypes like NIAW 3578, NIAW 3583, NIAW 3895 and NIAW 3771 indicating their tolerance nature. For Days to maturity, genotypes NIAW 3583 (0.69), NIAW 3991 (0.72), NIAW 3578 (0.73), Netravati (0.75) and NIAW 3983 (0.76) had less HSI and tolerate high temperature condition.

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