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Response of Wheat (*Triticum aestivum* L.) Genotypes to Heat Stress on Account of Delayed Sowing

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Abstract

Four wheat genotypes differing in cellular thermotolerance ratings were used in this study. Mean crop growth rate (CGR), leaf area index (LAI), leaf area duration (LAD), leaf area ratio (LAR), and specific leaf weight (SLW) decreased for all genotypes under heat stress on account on delayed sowing. Similarly, decrease in days to ear emergence, days to anthesis, days to maturity, grain filling duration (GFD) and grain filling rate (GFR) were recorded for all genotypes. Yield components, total grain yield, biological yield, and harvest index also decreased under heat stress. The decrease was more steep in genotypes with lower cellular thermotolerance as compared to genotypes with higher cellular thermotolerance.
Key words : Wheat genotypes, Heat stress, Delayed sowing.

High temperature stress is a major environmental stress limiting wheat (*Triticum aestivum* L.) productivity. It is estimated that in India alone, around 13.5 million ha of area under wheat is heat stressed (1). According to the recent assessment report of the Intergovernmental Panel on Climate Change, global earth temperatures have increased by 0.74 C in the last century, and are likely to increase by 1.1 to 6.4 C by 2100 which will further aggravate the problem (2). Plants have both inherent ability (basal tolerance) to survive at high temperature and ability to acquire tolerance to otherwise lethal temperatures. This acquisition of thermotolerance is an autonomous cellular phenomenon and is normally induced by gradual increase in temperature as would be experienced in natural environment (3). Genotypic differences in the induction of acquired thermotolerance (4, 5) and screening of wheat genotypes for thermotolerance on the basis of cell membrane thermostability (6) have been reported. Therefore in this study, contrasting wheat genotypes selected on the basis of cellular thermotolerance were evaluated for physiological and phenological responses, and performance of yield and its components.

Methods

Based on prior screening by the cell membrane thermostability assay at seedling and anthesis stages (7) four wheat genotypes, NW-1014 and DBW-14 (higher thermotolerance rating), and K-65 and Yangmai-6 (lower thermotolerance rating), were selected for this study. Field experiments were conducted at the Agricultural Farm, Institute of Agricultural Sciences, Banaras Hindu University at three dates of sowing (DOS) : 01 December (DOS I), 20 December (DOS II) and 10 January (DOS III) during the *rabi* season of 2009-10. The experiment was laid in randomized complete block design with three replications. The plot size was 2 × 3 m, with inter-row inter-plant spacing of 20 cm and 10 cm, respectively. The recommended dose of fertilizers and irrigations was supplied to the crop. Mean growth cycle temperature recorded an increment of 2.5 to 3 C and mean grain filling temperature showed an increment of 3.5 to 4 C at DOS III with respect to DOS I. Date to ear emergence was considered when most spikes appeared beyond the auricles of the flag leaf sheath (50% heading). The date at which 50% of the spikes flowered and the date at which grains attained maximum dry weight was recorded as the date of anthesis and date of maturity, respectively. Plants were sampled at 1—30 DAS, 31—60 DAS and at 61—90 DAS, respectively, to calculate for CGR (8), LAI (8), LAD (8), LAR

Table 1. Mean of crop growth rate ($\overline{CGR}$), leaf area index ($\overline{LAI}$), leaf area duration ($\overline{LAD}$), leaf area ratio ($\overline{LAR}$) and specific leaf weight ($\overline{SLW}$) of four wheat genotypes across different dates of sowing. *Values in parentheses indicate per cent decrease (-) with respect to DOS I.

Genotypes	$\overline{DOS}$	$\overline{CGR}$ (g. m^{-2} day^{-1})	$\overline{LAI}$	$\overline{LAD}$ (days)	$\overline{LAR}$ (dm^{2}g^{-1})	$\overline{SLW}$ (mg dm^{-2})
	I	7.2	2.0	48.8	98.9	363.9
	II	5.5	1.3	34.1	84.7	355.3
DBW-14		(-23.8)*	(-33.7)	(-30.3)	(-14.0)	(-2.3)
	III	4.6	0.7	20.1	65.4	316.8
		(-36.0)	(-62.2)	(-58.8)	(-34.0)	(-13.0)
	I	6.5	1.9	49.9	108.2	345.3
Yangmai-6	II	4.7	1.0	29.8	92.7	326.3
		(-27.8)	(-48.2)	(-40.2)	(-14.0)	(-5.5)
	III	3.3	0.5	14.9	70.6	286.5
		(-49.2)	(-73.8)	(-70.2)	(-35.0)	(-17.0)
	I	7.0	2.1	49.6	93.8	363.2
NW-1014	II	5.8	1.6	40.1	93.5	345.5
		(-17.5)	(-23.4)	(-19.0)	(-0.3)	(-4.9)
	III	4.1	0.8	22.1	64.1	320.3
		(-42.0)	(-60.0)	(-55.5)	(-32.0)	(-11.8)
	I	6.1	2.2	54.5	115.9	333.1
K-65	II	5.1	1.3	33.6	90.4	333.4
		(-17.2)	(-41.4)	(-38.4)	(-22.0)	(-0.1)
	III	3.3	0.6	15.6	74.7	294.3
		(-46.5)	(-74.0)	(-71.4)	(-36.0)	(-11.6)

(9), and SLW (9), respectively. The data of growth analysis parameters at all the growth stages were pooled to calculate the mean. GFD was recorded as the difference between the days taken to anthesis and days taken to maturity. GFR was estimated as the ratio between grain weight and GFD. Earheads per plant were counted and number of grains per earhead was calculated. For each replication, a 25 cm row length was harvested at maturity to determine 1,000-grain weight. Harvest index at maturity was calculated by taking the total grain yield with respect to the total dry matter produced above-ground. Standard statistical procedures for analysis of variance were followed and critical differences among means were tested at 0.05 probability level.

Results and Discussion

All mean growth analysis parameters were highest under normal sowing (DOS I) and declined as the temperature increased under late sown condition (Table 1). Maximum reduction was observed in DOS III. Maximum percent reduction in mean CGR was observed in Yangmai-6 (49.2%) and least percent reduction occurred in DBW-14 (36%). NW-1014 recorded least reduction in mean values of LAI, LAD and LAR with respect to other genotypes, while highest percent reduction was observed in K-65. Maximum percent decrease in mean SLW was observed in Yangmai-6. Similar result has been earlier cited (10). Significant decrease in number of days taken for ear emergence and anthesis for all genotypes under late sowing was also noted with a maximum reduction of 25 days (29.4%) in days to emergence and 27 days (29.7%) in days to anthesis in NW-1014 (Table 2). Number of days to maturity for all sowing dates was almost similar and was non-significant. Reductions to a large extent in the duration of developmental phases in wheat under late sowing have been highlighted by various workers (11—13). GFD under late sowing was highest in NW-1014, that is 31 days with the least 11.7% reduction, while K-65 suffered the

Table 2. Days to ear emergence, days to anthesis, days to maturity, grain filling duration (GFD) and grain filling rate (mg/day) of four wheat genotypes across different dates of sowing. *Values in parentheses indicate per cent decrease (-) with respect to DOS I.

Genotypes	DOS	Days to ear emergence	Days to anthesis	Days to maturity	GFD (days)	GFR (mg/ day)
	I	82	89	122	34	1.27
DBW-14	II	76	82	112	31	1.23
		(-7.3)	(-7.8)	(-8.2)	(-8.8)	(-4.0)
	III	59	64	90	27	1.16
		(-28.0)	(-28.1)	(-26.2)	(-20.6)	(-9.4)
	I	84	90	122	33	1.24
Yangmai-6	II	75	83	112	30	1.15
		(-10.7)	(-7.7)	(-8.2)	(-9.1)	(-7.0)
	III	61	66	90	25	0.81
		(-27.4)	(-26.7)	(-26.2)	(-24.2)	(-34.7)
	I	85	91	125	35	1.25
NW-1014		73	80	113	34	1.18
		(-14.1)	(-12.1)	(-9.6)	(-2.8)	(-5.6)
	III	60	64	94	31	1.07
		(-29.4)	(-29.7)	(-24.8)	(-11.4)	(-14.4)
	I	79	85	123	39	1.06
K-65	II	73	78	115	38	0.91
		(-7.6)	(-8.2)	(-6.5)	(-2.5)	(-14.0)
	III	59	64	92	29	0.73
		(-25.3)	(-24.7)	(-25.2)	(-25.6)	(-31.0)
Mean		72.4	78.0	109.2	32.2	1.1
CD (0.05)		1.3	1.2	NS	1.28	0.017

Table 3. Yield components, total grain yield (g/plant), total dry matter (g/plant) and harvest index (%) of four wheat genotypes across different dates of sowing. *Values in parentheses indicate per cent decrease (-) with respect to DOS I.

Genotypes	DOS	Earheads/ plant	Grains/ earhead	1000-grain weight (g)	Total grain yield (g/plant)	Total dry matter (g/plant)	Harvest index
DBW-14	I	3.8	42.9	43.3	6.94	14.92	46.55
	II	3.7	41.7	38.1	6.21	14.15	44.04
			(-2.7)*	(-12.0)	(-10.5)	(-5.2)	(-5.4)
	III	3.9	34.6	31.4	3.85	9.79	39.41
			(-19.3)	(-27.5)	(-44.5)	(-34.4)	(-15.3)
Yangmai-6	I	3.4	46.2	40.8	6.18	14.28	43.27
	II	3.4	43.8	34.4	4.95	13.10	37.85
			(-5.2)	(-15.8)	(-20.0)	(-8.3)	(-12.5)
	III	3.6	32.4	20.2	2.25	8.00	28.21
			(-29.8)	(-50.5)	(-63.6)	(-44.0)	(-35.0)
NW-1014	I	3.5	48.7	43.7	7.24	14.73	49.47
	II	3.5	48.3	40.2	6.41	14.15	45.47
			(-0.7)	(-8.0)	(-11.5)	(-4.0)	(-7.4)
	III	3.6	40.5	33.3	4.50	11.27	40.10
			(-16.8)	(-23.8)	(-38.0)	(-23.5)	(-18.4)
K-65	I	3.5	41.2	41.6	5.74	13.27	43.35
	II	3.7	41.1	34.5	5.07	13.16	38.62
			(-0.2)	(-17.0)	(-11.7)	(-0.8)	(-11.0)
	III	3.6	31.6	21.2	2.29	8.43	27.14
			(-23.4)	(-48.9)	(-60.0)	(-36.5)	(-37.4)
Mean		3.6	41.1	35.2	5.14	12.44	40.26
CD (0.05)		NS	0.85	0.44	0.29	0.60	1.37

maximum reduction of 25.6%. Yangmai-6 displayed a 34.7% decrement in GFR as compared to DBW-14 with a reduction of just 9.4%. Significant differences were obtained for grains per earhead and 1000-grain weight, with NW-1014 followed by DBW-14 exhibiting lesser reductions for both parameters, owing to high GFD for NW-1014 and high GFR for DBW-14 (Table 3). Yangmai-6 suffered maximum percent reduction for both grains per earhead and 1,000-grain weight, that is 29.8 and 50.5%, respectively. Late sowing also had significant adverse effect on harvest index and its components. Least reduction for total grain yield and total dry matter was recorded for NW-1014, whereas Yangmai-6 was the most adversely affected among all genotypes. K-65 sustained higher reduction in harvest index while DBW-14 reported least reduction. Similar reduction pattern in yield components under late sowing have also been documented earlier (13, 14).

Thus we conclude that the superior performance of NW-1014 and DBW-14 over Yangmai-6 and K-65 can be attributed to better stability in physiological parameters, GFD, GFR, yield components, and therefore grain yield under heat stress associated with delayed sowing. Higher 1000-grain weight and grain yield in NW-1014 and DBW-14 could suggest an association between cellular thermotolerance and adaptability under heat stress.

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