

## Physiological investigations on thermal stress tolerance in wheat

Multi-location Heat Tolerance trial (MLHT) was conducted to identify the temperature stress tolerant lines from AVT genotypes under testing in different trials under TS and LS conditions and from other promising entries. Two trials MLHT1 and MLHT2 (each with 16 entries for CZ and PZ trial and 25 entries for NWPZ and NEPZ trial) were conducted during the crop season 2018-19. Both MLHT1 and MLHT2 trials were sent to 15 locations and were conducted at all locations. The data from Dharwad, Indore, Niphad, Ranchi was not included in the MLHT1/MLHT2 analysis due to erroneous data in one of the two year and Faizabad centre due to trial rejection. Sowing was done under timely (November) and late sown (December) conditions with at least 21 days difference between the sowing dates to expose the crop to optimum and high temperature environments, respectively. The two trials were sown in 4 x 4 and 5 x 5 lattice square design for 16 and 25 entries with two replications. Observations on weather, growth and yield parameters were recorded at all the locations in the prescribed format. Physiological parameters *viz.* canopy temperature (CT), chlorophyll content index (CCI) and chlorophyll fluorescence (CFL) were recorded at 15 DAA and 21 DAA at Pune, Junagadh, Hisar, Pantnagar, Ludhiana, Kanpur, Karnal and Malda.

### **Magnitude of heat stress:**

- Compared to previous crop season minimum temperature across centres were higher by 0.6°C and 0.4°C under TS and LS conditions, respectively during vegetative phase. During reproductive phase, minimum temperature was higher by 0.6°C and 0.7°C under TS and LS conditions, respectively.
- Maximum temperature, compared to previous crop season during vegetative phase across centres were higher by 0.8°C & lower by 0.6°C under TS and LS conditions, respectively. However, the maximum temperature was lower by 1°C & 0.3°C under TS and LS conditions respectively during reproductive phase.
- The temperature during vegetative phase has remained cooler across the centres, but there was clear temperature difference during grain filling period under timely and late sown conditions indicating late sown trials were exposed to higher temperature during grain filling period.
- MLHT1 trial consisted the entries tested under 2018-19 and MLHT2 included the same set of entries tested in 2017-18 & 2018-19.

**Table 1: List of wheat genotypes identified as less heat sensitive (HSI < 1.0) in MLHT1&2 trials during 2018-19**

Trial	Zone	Genotypes
MLHT1	CZ&PZ	PBW823(0.65),PBW822(0.78),DBW277(0.80),DWAP1715(0.83),CG1029(0.86),HD3345(0.95) and RWP-2018-29 (0.95)
	NWPZ&NEPZ	HD3293(0.76), RWP-2018-32(0.87), RWP -2018-31(0.88), PBW821(0.88), DBW273(0.89), RWP-2018-27(0.89), RAJ4529(0.90), RWP-2018-26(0.92), PBW796(0.97), WH1239(0.97), DBW257(0.97)
MLHT2	CZ&PZ	HI1625(0.54),AKAW4924(0.66),RWP-2017-21(0.93),GW492(0.96),GW491(0.98), MP1338(0.98)
	NWPZ&NEPZ	HD3249(0.84), PBW771(0.88), PBW762(0.89), DBW221(0.91), K1601(0.91), BRW3792(0.95), DBW233(0.97), WH1218(0.97), PBW769(0.99)

Values in the paranthesis indicates Heat Sensitivity Index(HSI)

**Table 2a: HSI of MLHT1 genotypes in CZ&PZ, across locations and pooled during 2018-19**

Genotype	Heat Sensitivity Index						R%*
	Dharwad	Indore	Junagadh	Parbhani	Pune	Pooled	
CG1029	0.96	1.13	0.24	0.15	1.08	<b>0.86</b>	<b>23.2</b>
DBW277	0.03	1.03	1.21	0.74	0.74	<b>0.8</b>	<b>21.5</b>
DWAP1715	0.57	0.62	1.4	-0.88	1.21	<b>0.83</b>	<b>22.5</b>
GW509	1.04	0.82	1.39	1.62	0.94	1.06	28.5
HD3343	0.7	1.38	1.04	2.23	0.87	1.11	30
HD3345	1.33	0.68	0.75	1.02	0.95	<b>0.95</b>	<b>25.5</b>
HI1633	1.45	1.34	1.02	-0.38	1.08	1.14	30.9
PBW822	0.94	1.39	0.69	-1.28	0.9	<b>0.78</b>	<b>21</b>
PBW823	1.03	0.21	0.13	1.11	0.92	<b>0.65</b>	<b>17.6</b>
RWP-2018-29	-0.45	1.33	0.51	2.4	1.16	<b>0.95</b>	<b>25.7</b>
UAS3001	1.33	1.08	1.21	1.82	1.27	1.32	35.6
UAS3002	1.14	1.55	0.53	2.5	1.24	1.3	35
DBW14(C)	0.88	0.54	2.03	0.53	0.76	<b>0.99</b>	<b>26.6</b>
HD2932(C)	1.07	1.24	1.39	2.06	0.96	1.21	32.6
RAJ3765(C)	1.14	0.88	0.93	-0.48	0.95	<b>0.86</b>	<b>23.2</b>
WH730(C)	1.69	0.34	1.15	1.07	0.78	<b>0.98</b>	<b>26.4</b>

\*Reduction% in grain yield under LS compared to TS

**Table 2b: HSI of MLHT1 genotypes in NWPZ & NEPZ, across locations and Pooled during 2018-19**

Genotype	Heat Sensitivity Index									R%*
	Durgapura	Hisar	Kanpur	Karnal	Ludhiana	Malda	Pantnagar	Ranchi	Pooled	
DBW257	1	0.76	0.81	1.07	1.07	1.1	1.07	0.91	<b>0.97</b>	<b>35.2</b>
DBW273	0.76	1.03	0.41	0.98	0.5	0.87	1.16	1.38	<b>0.89</b>	<b>32.1</b>
HD3277	0.74	1.24	1.39	1.08	0.73	1.33	1.11	1.15	1.22	44.1
HD3293	0	0.87	0.61	0.66	1.03	0.91	0.64	1.14	<b>0.76</b>	<b>27.7</b>
NW7049	1.19	0.83	1.51	0.7	-0.25	1.04	0.96	1.25	1.11	40.2
PBW781	0.91	1.15	0.71	0.98	1.42	1.17	1.34	0.9	1	36.2
PBW796	0.78	0.78	1.37	1.05	0.34	0.66	0.62	1.29	<b>0.97</b>	<b>35.1</b>
PBW820	0.58	1.15	1.33	1.01	1.53	0.98	0.47	0.95	1.06	38.4
PBW821	0.91	1	0.83	1.23	0.75	0.89	0.82	0.75	<b>0.88</b>	<b>31.8</b>
RAJ4529	1.19	1.05	0.71	1.29	0.19	0.64	1.04	1.11	<b>0.9</b>	<b>32.6</b>
RWP-2018-26	1.04	1	0.38	1.12	1.2	1.04	0.95	0.64	<b>0.92</b>	<b>33.4</b>
RWP-2018-27	1.48	0.79	0.4	1.34	1.46	0.71	1.18	0.75	<b>0.89</b>	<b>32.2</b>
RWP-2018-28	1.1	0.91	0.12	1.38	1.15	0.84	0.98	0.91	1.02	36.9
RWP-2018-30	0.71	1.15	0.8	1.16	1.2	1.03	1.18	1.11	1.1	40
RWP-2018-31	1.4	1.28	1.42	1	-1.34	1.24	0.94	0.85	<b>0.88</b>	<b>31.8</b>
RWP-2018-32	1.22	0.73	0.41	1.08	0.91	1.07	0.72	1.03	<b>0.87</b>	<b>31.5</b>
SBP-MABB1	1.14	1.1	1.48	0.54	0.82	0.8	1.15	1.2	1.13	41
SBP-MABB2	1.33	1.05	1.41	0.85	1.66	1.15	0.79	0.65	1.18	42.9
WH1239	0.74	1.32	0.61	0.82	1.45	0.98	0.97	1.23	<b>0.97</b>	<b>35.1</b>
DBW14(C)	0.54	1	0.62	0.78	1.85	0.91	0.86	0.94	<b>0.89</b>	<b>32.1</b>
DBW150(C)	1.36	0.96	0.73	0.98	1.31	1.23	1.41	0.86	1.06	38.4
DBW71(C)	0.79	1.13	0.65	0.69	1.25	1	0.95	0.61	<b>0.84</b>	<b>30.3</b>
HD2932(C)	1.52	0.86	1.23	1.14	1.59	1.1	1.09	1.15	1.22	44.1
RAJ3765(C)	1.04	0.79	1.23	0.77	1.41	1.15	1.34	0.8	1.06	38.4
WH730(C)	1.33	1.12	0.2	1.11	-0.73	1.09	0.98	0.99	<b>0.85</b>	<b>30.8</b>

\*Reduction% in grain yield under LS compared to TS

**Table 3a: HSI of MLHT2 genotypes in CZ&PZ, across locations and pooled over years and locations**

Genotype	Heat Sensitivity Index				R%*
	Junagadh	Parbhani	Pune	Pooled	
AKAW4924	1.05	-5.53	1.11	<b>0.66</b>	<b>12.7</b>
DBW235	0.83	2.53	1.32	1.14	22
GW491	0.95	-1.05	1.27	<b>0.98</b>	<b>18.8</b>
GW492	0.9	2.06	0.8	<b>0.96</b>	<b>18.5</b>
GW 493	1	2.56	0.86	1.07	20.6
GW495	1.15	0.15	1.07	1.03	19.9
HI1624	0.98	2.37	0.75	1.15	22.2
HI1625	0.78	-1.4	0.74	<b>0.54</b>	<b>10.4</b>
MACS6709	1.05	0.8	1.07	1.04	20
MP1338	1.01	0.51	1.04	<b>0.98</b>	<b>18.9</b>
PBW770	1.1	1.65	1.01	1.09	20.9
RW5	1.03	2.09	0.98	1.07	20.7
RWP-2017-21	0.85	1.21	1.01	<b>0.93</b>	<b>18</b>
DBW150 (C)	1.25	0.36	0.81	1.01	19.4
HD2932 (C)	1.13	-0.66	0.95	<b>0.98</b>	<b>18.8</b>
WH730 (C)	0.91	2.3	1.1	1.25	24

\*Reduction% in grain yield under LS compared to TS

**Table 3b: HSI of MLHT2 genotypes in NWPZ & NEPZ, across locations and pooled over years and locations**

Genotype	Heat Sensitivity Index								R%*
	Durgapura	Hisar	Kanpur	Karnal	Ludhiana	Malda	Pantnagar	Pooled	
BRW3792	0.43	0.95	1.01	1.04	1.12	0.76	1.3	<b>0.95</b>	<b>22.6</b>
DBW221	0.39	0.9	1.21	0.97	1	0.85	0.84	<b>0.91</b>	<b>21.7</b>
DBW222	1.33	1.03	0.88	0.91	1.18	1.09	0.64	1.03	24.6
DBW223	1.25	0.98	1.27	1.4	0.87	0.8	0.86	1.05	25
DBW233	0.79	1.12	0.76	0.96	0.84	1.24	0.81	<b>0.97</b>	<b>23.1</b>
DBW237	0.72	1.05	1.75	1.38	1.13	1.17	0.72	1.18	28.1
HD3249	0.12	1.15	0.92	0.51	0.75	0.97	0.81	<b>0.84</b>	<b>20</b>
HD3254	0.63	1.15	0.67	0.94	1.49	0.78	1.66	1.06	25.3
HI1621	1.44	1.02	1.63	1.14	0.28	1.17	0.75	1.08	25.9
K1601	1.36	1	-0.05	1.09	1.15	0.8	1.45	<b>0.91</b>	<b>21.8</b>
PBW762	0.89	0.93	0.25	1.53	1.02	0.85	0.76	<b>0.89</b>	<b>21.3</b>
PBW763	1.74	0.89	1.44	0.27	1.31	1.33	0.21	1.12	26.8
PBW766	0.64	1.03	0.89	1	1.17	1.16	0.83	1	24
PBW769	0.87	0.97	0.84	1.27	0.89	1.02	1.29	<b>0.99</b>	<b>23.7</b>
PBW771	0.07	0.86	1.32	1.08	1.23	0.48	0.73	<b>0.88</b>	<b>21</b>
PBW773	1.1	0.78	1.17	1.52	0.9	1.16	0.72	1.05	25.2
RW5	0.98	1.09	1.42	0.39	0.89	0.97	1.05	1.02	24.3
RWP-2017-21	1.37	1.08	0.96	1.56	0.97	1.27	0.95	1.16	27.6
UP2981	1.65	0.9	0.34	1.97	1.03	1.43	0.88	1.14	27.3
WH1218	1.59	1.22	0.84	0.68	1.31	0.41	0.65	<b>0.97</b>	<b>23.2</b>
DBW14 (C)	0.86	1.22	0.08	-0.42	0.35	0.77	1.04	<b>0.63</b>	<b>15.1</b>
DBW150 (C)	0.4	0.96	1.83	0.93	1.25	1.09	1.23	<b>0.83</b>	<b>19.9</b>
DBW71 (C)	0.04	0.76	1.01	0.62	1.33	0.98	2.08	<b>0.98</b>	<b>23.4</b>
RAJ3765 (C)	1.32	0.98	0.74	0.65	0.62	0.89	0.57	1.1	26.2
WH730 (C)	2.07	0.99	1.04	0.49	0.37	1.28	1.87	1.15	27.6

\*Reduction% in grain yield under LS compared to TS

**Correlation of grain yield with different traits under late sown conditions**

The pooled analysis of the data over locations and over years indicated reduction in most of the measured traits under LS condition. In order to identify the trait association with yield under late sown conditions in different zones, the stepwise regression analysis revealed that, Days to maturity, Biomass and Harvest index had significant correlation with grain yield under CZ & PZ trials. whereas under NWPZ&NEPZ the Biomass, Harvest index and Chlorophyll fluorescence measured at 15DAA directly influenced the grain yield.