

Physiological Investigations on Heat and Drought Tolerance in Wheat

Multi-location Heat Tolerance Trial (MLHT) was conducted to identify the temperature and drought stress tolerant lines among AVT final year genotypes and checks planted under timely sown (TS), late sown (LS) and drought stress (DR) conditions. Two trials MLHT1 (16 entries for NWPZ and NEPZ) and MLHT2 (16 entries for CZ and PZ) were conducted during the crop season 2020-21 at 8 locations in each region and sowing was done under TS (November) and LS (December) conditions keeping at least 21 days difference between the two sowing dates to expose the crop to optimum and high temperature environments, respectively. In addition, one set of both the trials was also planted under drought stress condition with only presown irrigation. The trials were planted in 4 x 4 lattice square design with two replications. Observations on weather, growth and yield parameters were recorded at all the locations in the prescribed format. Physiological parameters namely Normalized Difference Vegetation Index (NDVI), Canopy Temperature (CT) and Chlorophyll Content Index (CCI) were recorded at 15 days after anthesis (DAA) and 21DAA at Karnal, Ludhiana, Hisar, Sabour, Indore, Junagadh, Vijapur, Dharwad and Pune. The data from Kanpur and Ranchi in MLHT1, while Pune (LS) and Niphad in MLHT2 were not included in pooled analysis due to unrealistic yields. One of the check entry did not germinate and hence data of 15 genotypes in each trial has been reported.

Magnitude of heat and drought stress:

- In NWPZ and NEPZ, the mean minimum and maximum temperature across centres was higher by 3.3°C and 4°C respectively, at reproductive stage in LS compared to TS conditions. The RH ranged from 50-80% and the rainfall received was more under TS condition compared to LS in both vegetative and reproductive phases.
- In CZ and PZ, the mean minimum and maximum temperature across centres was higher by 1.0°C and 1.3°C respectively, at reproductive stage of LS compared to TS conditions. The rainfall received was higher in vegetative phase at CZ centres whereas, minimal rainfall was received in PZ centres at both vegetative and reproductive phases.

Impact of heat/drought stress was adjudged by taking into account Heat Sensitivity Index (HSI) and Drought Sensitivity Index (DSI). HSI/DSI were calculated using the formula $HSI/DSI = (1 - YD/Yi) / (1 - XD/Xi)$ Where, YD and Yi are the grain yield for each genotype under stress and normal conditions respectively. XD and Xi are the trial mean grain yield under stress and control conditions respectively. For reference, HSI/DSI < 0.5 is considered as highly tolerant, HSI/DSI < 0.5-1 as moderately tolerant and HSI/DSI > 1.0 as susceptible genotypes.

Under heat stress, genotype DBW 333 showed lowest HSI (0.70) against best check NIAW3170 (0.77) in MLHT1 with a minimum yield reduction of 16.4%. Whereas, under drought condition, in MLHT1 the genotype DBW327 showed lower DSI (0.78) compared to the best check NIAW3170 (0.79) with a minimum yield reduction of 18.2%. Similarly, in MLHT2, GW513 showed lower DSI (0.8) as compared to the best check AKDW2997-16 (0.96) with a minimum yield reduction of 33% under drought stress.

Table 1: List of wheat genotypes identified as heat/drought tolerant during 2020-21.

| Trial | Zone | Genotypes | |
|-------|-----------|--|--|
| | | HSI<1 | DSI<1 |
| MLHT1 | NWPZ&NEPZ | DBW327(0.81), DBW333(0.7), JKW261(0.88). | DBW296(0.98), DBW327(0.78), DBW328(0.99), DBW333(0.98), HUW838(0.95), JKW261(0.93), WH1252(0.98). |
| MLHT2 | CZ&PZ | GW513(0.91), HI1636(0.71), MP1358(0.78). | GW513(0.8), MP1358(0.9). |

Values in the paranthesis indicates HSI/DSI

Correlation of grain yield under late sown and drought conditions with different traits

The correlation of different growth, yield and physiological traits with yield under late sown condition in both trials indicated that the grain yield is positively correlated with tiller number, biomass, harvest index and NDVI at 21 DAA, whereas it is negatively correlated with canopy temperature. The grain yield under drought condition in both the trials are positively correlated with biomass, tiller number, plant height and NDVI at one month after sowing and negatively correlated with canopy temperature.

Table 2: Correlations of grain yield with other traits under late sown (GYLS) and drought (GYDR) conditions (pooled)

| Traits | GYLS | GYDR |
|-----------------------------------|--------|--------|
| Days to heading | 0.23 | 0.32 |
| Days to maturity | 0.43 | 0.48 |
| Tiller number | 0.63* | 0.60* |
| Biomass | 0.71* | 0.67* |
| Thousand grain weight | 0.34 | 0.39 |
| Plant height | 0.46 | 0.73* |
| Harvest index | 0.69* | 0.47 |
| CT at 15DAA | -0.76* | -0.59* |
| CT at 21DAA | -0.67* | -0.64* |
| CCI at 15DAA | 0.36 | 0.43 |
| CCI at 21DAA | 0.23 | 0.39 |
| NDVI at 1month after germination. | 0.63 | 0.59* |
| NDVII at 21 DAA | 0.78* | 0.36 |

*Significant at p<0.05 level of significance

Table 3: Heat Sensitivity Index (HSI) of MLHT1 genotypes in NWPZ&NEPZ locations and pooled across locations during 2020-21

| Genotype | Location wise HSI | | | | | | Pooled | | | |
|---------------------|-------------------|-------|--------|----------|------|--------|--------|----------------|------|---------------------|
| | Durgapura | Hisar | Karnal | Ludhiana | Pusa | Sabour | HSI | Grain yield(g) | | % Reduction over TS |
| | | | | | | | | TS | LS | |
| DBW296 | 1.43 | 0.97 | 1.78 | 1.00 | 1.29 | 0.30 | 1.02 | 2106 | 1602 | 23.9 |
| DBW327 | 1.41 | 0.93 | 0.39 | 0.67 | 0.64 | 0.79 | 0.81 | 2166 | 1751 | 19.2 |
| DBW328 | 1.55 | 1.01 | 1.37 | 0.61 | 1.20 | -0.23 | 1.00 | 2105 | 1609 | 23.6 |
| DBW332 | 1.01 | 1.11 | 1.54 | 0.68 | 1.20 | 0.88 | 1.15 | 2057 | 1499 | 27.1 |
| DBW333 | 0.98 | 1.01 | 0.54 | 0.33 | 0.65 | 0.43 | 0.70 | 2064 | 1725 | 16.4 |
| HUW838 | 1.21 | 1.12 | 1.01 | 0.60 | 1.05 | 1.54 | 1.16 | 1703 | 1240 | 27.2 |
| JKW261 | 1.11 | 1.02 | 0.81 | 0.53 | 1.04 | 1.06 | 0.88 | 2183 | 1733 | 20.6 |
| WH1252 | 1.31 | 0.94 | 0.75 | 2.16 | 0.84 | 1.73 | 1.24 | 2016 | 1427 | 29.2 |
| DBW187 (C) | 0.92 | 1.11 | 1.73 | 1.91 | 1.30 | 1.39 | 1.30 | 2091 | 1449 | 30.7 |
| DBW303 (C) | 0.53 | 1.02 | 0.82 | 0.36 | 1.28 | 0.37 | 0.90 | 2113 | 1665 | 21.2 |
| HD3086 (C) | 0.80 | 1.04 | 0.27 | 1.48 | 0.58 | 1.44 | 0.98 | 2024 | 1555 | 23.2 |
| NIAW3170 (C) | 0.44 | 0.63 | 0.98 | 1.03 | 0.81 | 1.09 | 0.77 | 1997 | 1634 | 18.2 |
| PBW771 (C) | 1.23 | 1.03 | 0.17 | 0.51 | 0.90 | 1.29 | 0.89 | 2075 | 1642 | 20.8 |
| WH730 (C) | 0.08 | 1.02 | 1.32 | 1.67 | 0.98 | 1.05 | 0.98 | 1874 | 1441 | 23.1 |
| WH1270 (C) | 0.71 | 1.04 | 1.19 | 0.97 | 1.03 | 1.72 | 1.12 | 1969 | 1450 | 26.4 |

Table 4: Drought Sensitivity Index (DSI) of MLHT1 genotypes in NWPZ&NEPZ locations and pooled across locations during 2020-21

| Genotype | Location wise DSI | | | | | | Pooled | | | |
|---------------------|-------------------|-------|--------|----------|------|--------|--------|----------------|------|---------------------|
| | Durgapura | Hisar | Karnal | Ludhiana | Pusa | Sabour | DSI | Grain yield(g) | | % Reduction over IR |
| | | | | | | | | IR | DR | |
| DBW296 | 1.30 | 1.18 | 0.84 | 0.60 | 1.33 | 0.49 | 0.98 | 2106 | 1597 | 24.2 |
| DBW327 | 1.70 | 0.47 | 0.72 | 0.51 | 0.73 | 0.84 | 0.78 | 2166 | 1772 | 18.2 |
| DBW328 | 1.43 | 0.84 | 1.27 | 0.98 | 0.84 | 0.77 | 0.99 | 2105 | 1619 | 23.1 |
| DBW332 | 1.52 | 1.56 | 0.94 | 1.59 | 1.20 | 0.43 | 1.24 | 2057 | 1462 | 28.9 |
| DBW333 | 1.31 | 0.77 | 0.73 | 1.05 | 0.99 | 1.62 | 0.98 | 2064 | 1591 | 22.9 |
| HUW838 | 0.52 | 1.02 | 0.74 | 1.64 | 0.87 | 1.39 | 0.95 | 1703 | 1326 | 22.2 |
| JKW261 | 1.17 | 0.52 | 1.15 | 0.55 | 1.15 | 1.02 | 0.93 | 2183 | 1710 | 21.7 |
| WH1252 | 0.83 | 0.85 | -0.45 | 1.62 | 0.91 | 1.40 | 0.98 | 2016 | 1553 | 23.0 |
| DBW187 (C) | 0.50 | 1.30 | 0.86 | 1.41 | 0.71 | 1.03 | 0.95 | 2091 | 1626 | 22.3 |
| DBW303 (C) | 0.92 | 1.21 | 1.52 | 1.31 | 1.02 | 0.59 | 1.16 | 2113 | 1542 | 27.0 |
| HD3086 (C) | 1.07 | 1.05 | 0.70 | 1.25 | 0.97 | 0.87 | 1.01 | 2024 | 1545 | 23.7 |
| NIAW3170 (C) | 0.76 | 0.75 | 0.82 | 0.70 | 1.18 | 0.66 | 0.79 | 1997 | 1627 | 18.5 |
| PBW771 (C) | 1.47 | 1.70 | 0.74 | 1.05 | 0.90 | 1.36 | 1.19 | 2075 | 1496 | 27.9 |
| WH730 (C) | -0.84 | 1.17 | 2.58 | 0.33 | 1.32 | 1.42 | 1.23 | 1874 | 1333 | 28.9 |
| WH1270 (C) | 0.57 | 0.79 | 1.87 | 0.23 | 0.84 | 0.95 | 0.81 | 1969 | 1594 | 19.0 |

Table 5: Heat Sensitivity Index (HSI) of MLHT2 genotypes in CZ&PZ locations and pooled across locations during 2020-21

| Genotype | Location wise HSI | | | | | | Pooled | | | |
|--------------------------|-------------------|----------|---------|---------|---------|----------|--------|----------------------|------|---------------------|
| | Indore | Junagadh | Udaipur | Vijapur | Dharwad | Parbhani | HSI | Grain yield (g/plot) | | % Reduction over TS |
| | | | | | | | | TS | LS | |
| GW513 | 1.01 | 0.84 | 1.24 | 1.05 | 0.98 | 0.92 | 0.91 | 1812 | 1518 | 16.2 |
| HI1636 | 0.35 | 0.87 | 1.22 | 1.00 | 0.72 | 1.75 | 0.71 | 1730 | 1512 | 12.6 |
| MP1358 | 1.03 | 0.76 | 0.74 | 1.08 | 0.43 | 1.74 | 0.78 | 1807 | 1555 | 13.9 |
| AKDW2997-16(d)(C) | 1.44 | 1.71 | 1.50 | 0.23 | 0.93 | 1.04 | 1.33 | 1702 | 1301 | 23.6 |
| DDW47(d)(C) | 0.46 | 1.28 | 1.44 | 1.31 | 1.29 | 1.24 | 1.69 | 1824 | 1276 | 30.0 |
| HD3090 (C) | 0.81 | 1.02 | 1.15 | 0.71 | 0.74 | 0.35 | 0.77 | 1812 | 1563 | 13.7 |
| HI1544 (C) | 1.37 | 0.59 | 1.39 | 1.23 | 1.04 | -0.64 | 0.93 | 1813 | 1513 | 16.5 |
| HI1605 (C) | 0.57 | 1.09 | 0.83 | 1.42 | 1.36 | 0.77 | 1.11 | 1956 | 1571 | 19.7 |
| HI8805(d) (C) | 2.46 | 0.96 | 0.61 | 1.03 | 1.24 | 1.26 | 1.34 | 1872 | 1426 | 23.8 |
| HI8823(d) | 0.85 | 1.18 | 0.74 | 0.62 | 1.50 | 0.23 | 1.08 | 1861 | 1505 | 19.1 |
| MACS3949(d) (C) | 1.33 | 0.75 | 0.51 | 0.83 | 1.03 | 1.21 | 1.01 | 1797 | 1476 | 17.8 |
| MACS4058(d) (C) | 0.52 | 1.16 | 0.79 | 1.18 | 1.30 | 0.14 | 0.64 | 1535 | 1361 | 11.4 |
| MP3288 (C) | 0.94 | 1.14 | 1.13 | 1.31 | 0.53 | 0.02 | 0.76 | 1750 | 1513 | 13.6 |
| UAS446(d)(C) | 0.39 | 1.25 | 1.39 | 0.75 | 1.06 | 1.91 | 1.37 | 1808 | 1370 | 24.2 |
| WH730 (C) | 1.12 | 0.27 | -0.56 | 0.97 | 0.39 | 0.96 | 0.33 | 1396 | 1314 | 5.9 |

Table 6: Drought Sensitivity Index (DSI) of MLHT2 genotypes in CZ&PZ locations and pooled across locations during 2020-21

| Genotype | Location wise DSI | | | | | | | Pooled | | | |
|--------------------------|-------------------|----------|---------|---------|---------|----------|------|--------|----------------|------|---------------------|
| | Indore | Junagadh | Udaipur | Vijapur | Dharwad | Parbhani | Pune | DSI | Grain yield(g) | | % Reduction over IR |
| | | | | | | | | | IR | DR | |
| GW513 | 1.86 | 0.94 | 0.51 | 0.72 | 0.81 | 0.73 | 0.52 | 0.80 | 1812 | 1206 | 33.4 |
| HI1636 | -0.72 | 1.02 | 1.39 | 0.79 | 0.78 | 1.12 | 0.74 | 1.01 | 1730 | 1001 | 42.2 |
| MP1358 | 1.11 | 0.90 | 0.60 | 1.11 | 0.70 | 1.21 | 0.93 | 0.90 | 1807 | 1128 | 37.6 |
| AKDW2997-16(d)(C) | 1.69 | 1.03 | 1.21 | 0.63 | 1.02 | 0.89 | 1.18 | 0.96 | 1702 | 1017 | 40.2 |
| DDW47(d)(C) | 0.56 | 1.08 | 0.96 | 1.25 | 1.16 | 1.08 | 1.28 | 1.13 | 1824 | 959 | 47.4 |
| HD3090 (C) | 1.44 | 0.97 | 1.00 | 1.20 | 0.81 | 0.93 | 0.98 | 1.06 | 1812 | 1011 | 44.2 |
| HI1544 (C) | 1.97 | 0.93 | 0.55 | 1.19 | 0.91 | 0.81 | 0.96 | 0.94 | 1813 | 1102 | 39.2 |
| HI1605 (C) | 0.39 | 0.99 | 1.22 | 1.02 | 1.21 | 0.87 | 0.69 | 1.01 | 1956 | 1126 | 42.5 |
| HI8805(d) (C) | 1.59 | 1.04 | 1.44 | 0.71 | 1.09 | 0.74 | 1.04 | 1.03 | 1872 | 1062 | 43.2 |
| HI8823(d) | -0.24 | 1.06 | 1.37 | 1.05 | 1.30 | 1.03 | 1.41 | 1.12 | 1861 | 987 | 47.0 |
| MACS3949(d) (C) | 0.03 | 1.02 | 1.20 | 1.07 | 1.19 | 1.04 | 1.32 | 1.11 | 1797 | 965 | 46.3 |
| MACS4058(d) (C) | 0.19 | 1.04 | 1.18 | 1.17 | 1.07 | 0.82 | 1.14 | 0.98 | 1535 | 902 | 41.3 |
| MP3288 (C) | 2.49 | 1.02 | 0.48 | 0.93 | 1.06 | 0.96 | 0.74 | 0.96 | 1750 | 1050 | 40.0 |
| UAS446(d)(C) | 0.79 | 1.04 | 1.22 | 1.03 | 1.17 | 1.30 | 1.02 | 1.09 | 1808 | 979 | 45.8 |