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# Response of spring wheat (*Triticum aestivum*) genotypes under changing environment during grain filling period

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In north-western plains of India, wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is grown under sub-tropical environment during November to April with mild winter. Though the environment is highly productive, it is vulnerable to high temperature stress during grain development phase of the crop (Nagarajan and Rane 2002). In some years hot dry wind blows from Thar desert of Rajasthan at grain filling stage and causes extensive damage to wheat crop. The wheat crop season of 2003-04 witnessed a sudden increase in temperature during March which coincided with grain development phase and resulted in loss of 4.6 million tonnes of grain at national level due to advancement of maturity and reduction in 1 000-grain weight (Samra and Singh 2005). In the present study, the genotypic response and adaptability for such heat shock was studied in 20 diverse bread wheat cultivars and were compared with their performance in the previous season that had normal cool weather.

Twenty spring wheat (*Triticum aestivum* L emend. Fiori and Paol) genotypes whose brief description is given in Table 1 were selected for this study. The experiment was conducted in sandy loam soil of IARI farm at New Delhi and a randomized block design with 3 replications was followed. The crop was raised during 2002–03 and 2003–04 crop seasons as timely sown (15th November ) and each genotype was grown in a plot size of 5 m × 1.38 m (6 rows of 5 m length with 23 cm space between rows). A seed rate of 10 g/ $m^2$ was used to maintain uniform population of about 350 plants/$m^2$ after making adjustment for seed size. N, $P_2O_5$ and $K_2O$ were applied @ 60, 40 and 40 kg/ha respectively at the time of seed bed preparation, and another split dose of N was applied @ 60 kg/ha at 30 days after sowing. Care was taken to avoid moisture stress by ensuring timely irrigation.

Days to anthesis and physiological maturity were recorded when 75% of the population in each plot reached these phenological stages. For grain yield, 1 $m^2$ area with uniform population in each plot was selected avoiding border rows. From the harvested yield, 1 000-grain weight was measured. Daily maximum and minimum temperatures during crop season were obtained from a nearby observatory. Statistical analysis was carried out by employing two factor randomized complete block design using MSTATC software.

Table 1 Brief description of the genotypes used in the study

| Genotype | Plant height | Maturity | Production condition |
|---|---|---|---|
| 'HD 2329' | Double dwarf | Medium early | Irrigated, timely sown |
| 'HD 2009' | Double dwarf | Medium early | Irrigated, timely sown |
| 'WH 147' | Double dwarf | Medium early | Irrigated, timely sown |
| 'RS 853' | Double dwarf | Medium early | Irrigated, timely sown |
| 'WH 542' | Double dwarf | Medium late | Irrigated, timely sown |
| 'RS 854' | Single dwarf | Medium late | Irrigated, timely sown |
| 'HD 2733' | Double dwarf | Medium late | Irrigated, timely sown |
| 'HW 2045' | Single dwarf | Medium early | Irrigated, late sown |
| 'HD 2501' | Single dwarf | Medium early | Irrigated, late sown |
| 'HD 2285' | Double dwarf | Early | Irrigated, late sown |
| 'UP 2338' | Single dwarf | Medium early | Irrigated, timely & late sown |
| 'PBW 343' | Single dwarf | Medium late | Irrigated, timely sown |
| 'HD 2865' | Double dwarf | Medium late | Rainfed, timely sown |
| 'DL 153-2' | Single dwarf & medium tall | Medium late | Rainfed, timely sown |
| 'HD 2784' | Single dwarf | Medium late | Rainfed & irrigated timely sown |
| 'PBW 175' | Single dwarf & medium tall | Medium late | Rainfed, timely sown |
| 'HD 2781' | Single dwarf | Medium late | Rainfed, timely sown |
| 'HDR 77' | Single dwarf & medium tall | Medium early | Rainfed, late sown |
| 'K 8027' | Single dwarf & medium tall | Medium late | Rainfed, timely sown |
| 'C 306' | Tall | Medium late | Rainfed, timely sown |

Data from Kundu and Nagarajan (1998). RS numbers are those in advanced trial. Early, medium and late refers to 110,125 and 135 days respectively. Timely and late refer to sowings in the first fortnight of November and third week of December respectively.

* Short note

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Table 2 Phenology, grain yield and 1 000 grain weight recorded during 2002-03 and 2003-04 crop seasons for different wheat genotypes under timely sown conditions

| Genotype | 2002–03 season | | | | | | 2003–04 season | | | | | | Per cent loss in | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days to | | Grain growth duration | Grain yield/m² | Grain growth rate | 1000 grain wt (g) | Days to | | Grain growth duration | Grain yield/m² | Grain growth rate | 1000 grain wt (g) | Grain yield | 1000 grain wt |
| | Anthesis | Maturity | | | | | Anthesis | Maturity | | | | | | |
| 'HD 2329' | 79 | 126 | 47 | 558 | 11.9 | 41.7 | 85 | 118 | 33 | 283 | 8.6 | 39.8 | 49.4 | 4.6 |
| 'HD 2009' | 86 | 125 | 39 | 436 | 11.2 | 37.2 | 83 | 117 | 35 | 204 | 6.0 | 32.3 | 53.1 | 13.0 |
| 'WH 147' | 81 | 135 | 54 | 398 | 7.4 | 45.4 | 88 | 122 | 33 | 259 | 7.6 | 40.3 | 34.8 | 11.2 |
| 'RS 853' | 87 | 133 | 46 | 570 | 12.4 | 42.5 | 86 | 127 | 41 | 333 | 8.1 | 40.9 | 41.5 | 3.9 |
| 'WH 542' | 85 | 137 | 52 | 467 | 9.0 | 35.2 | 91 | 134 | 43 | 357 | 8.3 | 31.7 | 23.6 | 10.0 |
| 'RS 854' | 87 | 132 | 46 | 493 | 10.7 | 44.3 | 86 | 121 | 35 | 419 | 12.0 | 41.3 | 15.0 | 6.8 |
| 'HD 2733' | 89 | 131 | 42 | 461 | 11.0 | 39.9 | 84 | 115 | 30 | 272 | 8.8 | 37.6 | 41.0 | 5.9 |
| 'HW 2045' | 79 | 135 | 56 | 385 | 6.9 | 46.6 | 85 | 124 | 39 | 268 | 6.9 | 42.9 | 30.3 | 8.1 |
| 'HD 2501' | 86 | 129 | 43 | 350 | 8.1 | 39.1 | 85 | 126 | 40 | 238 | 5.8 | 39.6 | 32.1 | –1.4 |
| 'HD 2285' | 81 | 124 | 43 | 365 | 8.5 | 44.7 | 82 | 120 | 37 | 261 | 6.9 | 42.1 | 28.5 | 5.7 |
| 'UP 2338' | 86 | 129 | 43 | 420 | 9.8 | 38.4 | 90 | 126 | 36 | 404 | 11.2 | 33.4 | 3.6 | 13.0 |
| 'PBW 343' | 87 | 133 | 46 | 562 | 12.2 | 39.2 | 88 | 126 | 38 | 307 | 8.1 | 37.2 | 45.4 | 4.9 |
| 'HD 2865' | 85 | 131 | 46 | 276 | 6.0 | 43.4 | 82 | 122 | 40 | 226 | 5.6 | 39.6 | 18.1 | 8.7 |
| 'DL 153-2' | 83 | 125 | 42 | 362 | 8.6 | 47.1 | 85 | 126 | 40 | 330 | 8.0 | 43.4 | 8.6 | 7.9 |
| 'HD 2784' | 83 | 125 | 42 | 320 | 7.6 | 45.1 | 87 | 126 | 40 | 314 | 7.9 | 40.3 | 1.6 | 10.5 |
| 'PBW 175' | 87 | 131 | 44 | 338 | 7.7 | 41.2 | 86 | 132 | 46 | 355 | 7.7 | 38.9 | –5.1 | 5.6 |
| 'HD 2781' | 87 | 134 | 47 | 320 | 6.8 | 48.0 | 88 | 135 | 47 | 372 | 7.9 | 42.2 | –16.6 | 12.1 |
| 'HDR 77' | 86 | 128 | 42 | 322 | 7.7 | 41.9 | 84 | 118 | 34 | 296 | 8.7 | 39.8 | 8.3 | 4.9 |
| 'K 8027' | 93 | 137 | 44 | 277 | 6.3 | 41.5 | 92 | 121 | 29 | 241 | 8.3 | 39.8 | 13.1 | 4.1 |
| 'C 306' | 90 | 135 | 45 | 320 | 7.1 | 41.5 | 87 | 119 | 32 | 275 | 8.6 | 37.7 | 13.8 | 9.2 |
| Mean | 85 | 131 | 46 | 400 | 8.7 | 42.2 | 86 | 124 | 38 | 301 | 7.9 | 39.0 | 22.0 | 7.4 |
| CV(%) | 1.47 | 0.90 | 1.92 | 8.5 | | 1.92 | | | | | | | | |
| LSD (*P*<0.05) | | | | | | | | | | | | | | |
| Year | 0.163 | 0.160 | 0.182 | 3.76 | | 0.101 | | | | | | | | |
| Genotypes | 0.514 | 0.506 | 0.674 | 11.87 | | 0.319 | | | | | | | | |
| Year× genotypes | 0.729 | 0.716 | 0.847 | 16.79 | | 0.451 | | | | | | | | |

In both seasons the maximum temperature increased above 20⁰C only after 75 days after sowing and hence flowering occurred 85 days after sowing in all genotypes. In the cool season (2002–03), the maximum temperature increased above 30⁰ C after 35 days of anthesis, whereas in the hot season (2003–04), the temperatures were above 30⁰C after 20 days of anthesis. A similar increase in minimum temperature to the tune of 5 to 8⁰C above the cool season was noticed in the hot season for about 10 days during grain filling period of the crop. During this period the plants experienced heat shock conditions. The two seasons' mean maximum and minimum temperatures were 22.8/9.1⁰ C and 22.8/9.8 ⁰C respectively. The values during reproductive phase were 26.4/13.0 ⁰C and 29.9/13.7⁰C for the cool and hot seasons respectively. Even though there was no perceptible difference in the whole season mean maximum and minimum temperatures, significant increase in these values were observed between cool and hot season crop during grain filling phase.

Days to anthesis and to physiological maturity, grain yield and thousand grain weights for the two seasons are given in Table 2. In both seasons, the anthesis time was nearly the same for all the genotypes. But the days to maturity advanced in the hot season that reduced the grain filling period significantly in many genotypes. Genotypes 'HD 2329', 'HD 2009', 'RS 853' and 'PBW 343' suffered more than 40% loss in grain yield in hot season compared to cool season. The per cent reduction in 1 000 grain weight was much lower than that in grain yield and maximum reduction was observed in 'HD 2009', 'WH 147', 'WH 542', 'UP

2338', 'HD 2784' and 'HD 2781' (Table 2). It has been reported that when the temperature is suddenly increased (33 to 40$^0$C) for 4 days at the critical grain filling stages, grain yield can decline by 23% (Stone and Nicolas 1994). Earliness is an important factor for adaptation to heat stress since early maturing varieties escape late occurring heat stress (He and Rajaram 1994, Lillemo *et al.* 2005 ). In hot season, 'C 306', 'K 8027', 'HDR 77', 'UP 2338' and 'RS 854' have advanced their maturity by about 11 days and thereby escaped the damage due to heat shock. However, they compensated their reduced grain growth period by increased grain growth rate and suffered less loss in grain weight during hot season. 'HD 2781', 'PBW 175' , 'HD 2784' and 'DL 153-2' were able to withstand the high heat condition as they had nearly the same grain growth duration and grain growth rate in cool and hot seasons. Those genotypes that escaped heat shock by hastened maturity suffered less loss in 1 000 grain weight. Others, like 'HD 2781', HD 2784' and 'DL 153-2' suffered greatly due to longer exposure to high temperature stress. 'PBW 175' was found to be highly adapted to sudden increase in temperature as it had minimum loss in grain yield and grain weight even though it was exposed to high level of heat stress during grain development period. Genotypes such as 'HD 2329', 'HD 2009', 'RS 853', 'HD 2733' and 'PBW 343' showed very high grain growth rates and had greater grain yield in cool season. In hot season both grain growth duration and grain growth rate decreased significantly in these genotypes leading to much greater loss in grain yield. In 'WH 147' and 'HW 2045', the greater loss in yield was mainly due to drastic reduction in grain growth duration, which was not compensated by increase in grain growth rate. It has been reported that reduction in grain weight in response to heat stress during grain growth was related to reduction in grain growth duration rather than grain growth rate (Shpiler and Blum 1991). However, He and Rajaram (1994) observed that grain filling rate was more temperature sensitive than days to anthesis or duration of grain filling. Our results showed that both grain growth rate and grain growth duration were affected by high temperature and were responsible for reduced yields.

With the exception of 'UP 2338', all genotypes that showed less yield reduction under sudden heat stress were released for rainfed condition and are potentially poor yielding types. Hoogendorn and Gale (1988), using near isogenic lines found that semi-dwarf and tall lines differed very little for heat-tolerance but double dwarfs were more sensitive to heat during grain filling. Our study is in conformity with this observation as most of the genotypes, which showed low yield reduction due to high temperature during grain growth, were either semi-dwarf or tall types.

North-western India needs wheat cultivars that are capable of high yields when the weather is beneficial but produce stable yields when conditions are adverse. The response of a range of bread wheat genotypes to heat shock conditions was investigated and adapted genotypes were identified. Tall and semi-dwarf genotypes were better adapted than double dwarf genotypes. Except 1 cultivar, most of them were potentially poor yielding types that can be used as parental material for development of genotypes suited for both favouarble and adverse environments.

## SUMMARY

Twenty diverse wheat (*Triticum aestivum* L. emend. Fiori and Paol) genotypes were grown in field for two consecutive seasons during 2002–04 as normal sown crop at IARI farm, New Delhi. The first season was normal cool winter and the second season was characterized by sudden increase in temperature during active grain filling period that raised the mean maximum and minimum temperatures by 7 and 6$^0$C respectively. Grain yield varied between 276 and 570 g/m$^2$ in the cool season and between 204 and 419 g/m$^2$ in the hot season. The adapted genotypes escaped the heat by maturing early and compensated the reduced grain growth period by enhanced grain growth rate or tolerated the heat stress with minimum change in their grain growth duration and grain growth rate as compared to cool season. Most of the genotypes that had low susceptibility to high temperature stress were potentially low yielding types and these genotypes if combined with high yield potential will perform well under both optimum as well as heat shock conditions as it happened in the second year trial.

## REFERENCES

He Zhong-hu and Rajaram S. 1994. Differential responses of bread wheat characters to high temperature. *Euphytica* **72**: 197–203.

Hoogendorn J and Gale M.D. 1988. The effects of dwarfing genes on heat tolerance in CIMMYT germplasm. (*in*) *Cereal Breeding Related to Integrated Cereal Production*, pp 61–6. Proceedings of the Conference of the Cereal Section of EUCARPIA, Wagenengen, The Netherlands.

Kundu, S and Nagarajan S. 1998. *Distinguishing characters of Indian Wheat Varieties,* 66 p. Research Bulletin No.4, Directorate of Wheat Research, Karnal, India.

Lillemo M, Van Ginkel M, Trethowan R M, Hernandez E and Crossa J. 2005. Differential adaptation of CIMMYT bread wheat to global high temperature environments. *Crop Science* **45**: 2 443–53.

Nagarajan S and Rane J. 2002. Physiological traits associated with yield performance of spring wheat (*Triticum aestivum)* under late-sown conditions. *Indian Journal of Agricultural Sciences* **72**: 135–40.

Samra J S and Singh G. 2005. *Heat wave of March, 2004: Impact on agriculture*. Research Bulletin, Indian Council of Agricultural Research, New Delhi, India.

Shpiler L and Blum A. 1991. Heat tolerance for yield and its components in different cultivars. *Euphytica* **51**: 257–63.

Stone P J and Nicolas M E. 1994. Wheat cultivars vary widely in their responses of grain yield and quality to short periods of post anthesis heat stress. *Australian Journal of Plant Physiology* **21**: 887–900.