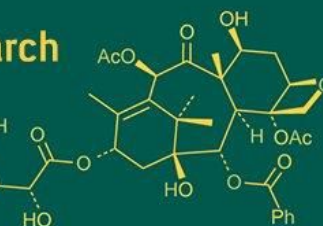


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Inheritable evaluation of wheat (*Triticum aestivum* L.) genotypes under late sown conditions in Malwa region of India

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Abstract

The present investigation was undertaken to evaluate the extent of genetic variability among sixty wheat (*Triticum aestivum* L.) genotypes, including two local checks (Lok-1 and Tejas), under late sown conditions during the Rabi 2024-25 season. The experiment was conducted at the Demonstration-cum-Experimental Farm, Shri Vaishnav Institute of Agriculture, using a randomized block design with two replications. Data were recorded on important agronomic and physiological traits such as germination percentage, ground cover, days to heading, days to anthesis, days to maturity, plant height, spike length, grain yield, and 1000-grain weight.

The analysis of variance revealed significant differences among the genotypes for most of the studied traits, indicating the presence of substantial genetic variability even under late sown conditions. Several genotypes performed better than the standard checks, reflecting their adaptability and tolerance to terminal heat stress commonly associated with delayed sowing. In particular, genotypes such as NINGA #1 exhibited superior grain yield along with desirable physiological traits, suggesting their potential utility in breeding programs targeting heat stress tolerance.

The variation observed for key yield and phenology-related traits under late sowing highlights the importance of exploiting both phenotypic and genetic diversity for the development of climate-resilient and high-yielding wheat cultivars. Late sown conditions generally expose the crop to higher temperatures during reproductive and grain-filling stages, which adversely affect yield; therefore, the identification of genotypes with better performance under such stress environments is crucial.

The findings of this study emphasize the significance of evaluating wheat genotypes under late sown conditions, which serve as an effective screening environment for identifying heat-tolerant genotypes. The identification of stable and high-performing genotypes under delayed sowing is essential for sustaining wheat productivity under changing climatic scenarios. Overall, the results provide valuable insights for breeders, indicating that the promising genotypes identified in this study can be effectively utilized in future breeding strategies aimed at improving yield stability, heat stress tolerance, and adaptability across diverse agro-climatic regions.

Keywords: Wheat, heat stress tolerance, late sown, genetic variability, *Triticum aestivum*, yield, climate resilience

Introduction

Wheat (*Triticum aestivum* L.) is one of the world's most important staple food crops, ranking among the top three cereals and contributing substantially to global food security. It serves as a primary source of calories and protein for a large proportion of the global population. In India, wheat is second only to rice, contributing about 35.5% of total food grain production and occupying nearly 21.8% of the cultivated land (Directorate of Economics and Statistics, 2021) [21]. Its wide adaptability to diverse agro-climatic conditions has facilitated extensive cultivation across the country, supporting both domestic food requirements and export potential.

Although wheat cultivation has traditionally been concentrated in the northern plains—particularly Punjab and Haryana—its geographical spread has expanded to several other states owing to improvements in agronomic management and varietal development. Major wheat-producing states now include Uttar Pradesh, Madhya Pradesh, Rajasthan, Bihar, and Maharashtra. However, a substantial proportion of wheat in these regions is frequently exposed to late sowing, mainly due to delayed harvest of preceding crops such as rice,

sugarcane, or cotton. Late sown wheat often encounters higher temperatures during reproductive and grain-filling stages, leading to reduced yield and grain quality.

Nutritionally, wheat is a rich source of carbohydrates, proteins, vitamins (B and E), minerals (calcium and iron), and dietary fiber. Among the 25 recognized wheat species worldwide, only three are cultivated commercially in India: *T. aestivum* (bread wheat), *T. durum* (macaroni wheat), and *T. dicoccum* (emmer wheat). The genetic diversity within these species has enabled breeders to develop varieties suited to diverse environments, including stress-prone conditions such as delayed sowing.

As a C₃ crop, wheat is highly sensitive to environmental fluctuations, particularly temperature stress. Late sowing exposes the crop to terminal heat stress, which accelerates phenological development, shortens the grain-filling duration, and adversely affects yield-related traits. Other associated factors such as nutrient imbalances, pest incidence, and irregular irrigation further aggravate yield losses under late sown conditions. These constraints pose a serious challenge to sustaining wheat productivity under changing climatic scenarios.

Global demand for wheat is projected to increase by nearly 60% by 2050, requiring a significant rise in productivity from the current average of 2.6 t/ha to about 3.5 t/ha.

In this context, the present study evaluates wheat genotypes under late sown conditions to assess the extent of genetic variability and to identify high-yielding, stable genotypes with desirable agronomic and physiological traits under terminal heat stress. The findings are expected to provide valuable insights for wheat breeding programs aimed at developing climate-resilient varieties capable of sustaining productivity and ensuring food security across diverse agro-climatic regions.

Materials and Methods

Experimental Site

The field experiment was conducted during the Rabi season of 2024-25 at the Demonstration-cum-Experimental Farm, Shri Vaishnav Institute of Agriculture, Indore, Madhya Pradesh, India. The site falls under a semi-arid agro-climatic zone characterized by hot summers and mild winters, which are suitable for wheat cultivation.

Climatic Conditions

Meteorological data (daily maximum and minimum temperatures) were recorded throughout the crop growth period to assess the prevailing climatic conditions. The Late sown (LS) crop experienced moderate temperatures during most growth stages, providing a favourable environment for optimal vegetative development, reproductive growth, and grain filling.

Experimental Material

A total of 60 wheat (*Triticum aestivum* L.) genotypes were procured from CIMMYT, TPE 3 trial Mexico, developed specifically for heat tolerance and other abiotic stress adaptations.

Two local check varieties, Lok-1 and Tejas, were included as standard controls.

Experimental Design

The experiment was laid out in a Randomized Block Design (RBD).

Late Sown: 15 December 2024

Experimental details

Treatments: 60 genotypes + 2 check varieties (Lok-1, Tejas)

Plot size: 3 m × 20 cm × 4 rows (row spacing: 20 cm)

Total plots: 180

Sowing and Irrigation Schedule

Sowing was done manually using line sowing with recommended spacing. Irrigations were scheduled at critical growth stages.

LS irrigation schedule

1st: 8th December 2024

2nd: 10th January 2025

3rd: 7 February 2025

Harvesting

Manual harvesting was done at physiological maturity:

LS: 5 April 2025

Soil Analysis and Nutrient Management

Pre-sowing soil analysis showed:

Nitrogen (N): 155 kg/ha

Phosphorus (P): 13.3 kg/ha

Potassium (K): 132 kg/ha

Fertilizer application followed the recommended dose of N:P:K = 120:60:40 kg/ha. Phosphorus and potassium were applied as basal doses, and nitrogen was split as:

- 50% at sowing
- 25% at tillering
- 25% at booting stage

Agronomic Practices

Standard agronomic practices for wheat were followed, including weed control through two manual weeding and appropriate plant protection measures for pest and disease management.

Observations Recorded

To evaluate the performance of the genotypes, observations were recorded from five randomly selected plants in each plot. The following traits were studied to assess growth, development, and yield performance:

1. **Germination Percentage:** This trait was recorded to understand the seed viability and establishment ability of the crop, especially under stress conditions.
2. **Ground Cover Percentage:** It reflects the early vegetative growth and canopy spread of the plants, which helps in better soil moisture conservation and reduces weed competition.
3. **Phenological Traits**
 - **Days to Heading:** Number of days taken from sowing to the emergence of spikes.
 - **Days to Anthesis:** Time taken from sowing to flowering.
 - **Days to Maturity:** Total duration from sowing to physiological maturity of the crop.
4. **Plant Height (cm):** Measured to assess vegetative growth. While good height indicates vigorous growth, excessive height may increase the chances of lodging.
5. **Spike Length (cm):** An important yield-contributing character, as longer spikes generally produce more grains.

6. **Grain Yield (g per plot):** The total grain weight harvested from each plot, representing overall productivity.
7. **1000-Grain Weight (g):** This indicates grain size and the efficiency of grain filling, which directly influences yield and grain quality.

Correlation Analysis

Pearson's correlation coefficient (r) was computed to determine the relationships among different quantitative traits of wheat under timely sown conditions. The coefficient was calculated using the formula:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

where: n = number of observations

- x and y = values of the two variables being compared
- $\sum xy$ = sum of the products of paired scores
- $\sum x^2$ and $\sum y^2$ = sum of squares of each variable
- $\sum xy$ = sum of the products of paired scores
- $\sum x^2$ and $\sum y^2$ = sum of squares of each variable

$$\sum x^2 \text{ and } \sum y^2 = \text{sum of squares of each variable}$$

Positive correlation values indicate that the two traits increase together, whereas negative values indicate an inverse relationship.

Statistical Analysis

Data were analysed using OPSTAT and Microsoft Excel. The following parameters were estimated:

- Analysis of Variance (ANOVA)
- Correlation coefficients

Results and Discussion

Analysis of Variance (ANOVA)-Late Sown Genotypes

The analysis of variance (Table 1) revealed significant differences ($p < 0.05$) among wheat genotypes for most of the recorded traits under late sown conditions, indicating the presence of considerable genetic variability even under delayed sowing and terminal heat stress. Replication effects were significant for a few traits, particularly germination (%) and ground cover (%), reflecting environmental influence; however, genotype effects remained highly significant for the majority of traits.

In Table-1 the Analysis of Variance (ANOVA) for Late sown wheat genotypes indicates significant variation among treatments (genotypes) for all studied traits, underscoring distinct genetic differences under normal sowing conditions.

Table 1: Result Interpretation-Late Sown Genotypes Performance

Parameter	Replication	Treatment	Error
DF	1.00	59.00	59.00
Ground cover%	3100.83	15.13	7.61
Germination%	3100.83	15.13	7.61
Days to Maturity	418.13	16.23	4.95
Days to Heading	297.68	10.92	2.17
Days to Anthesis	323.41	8.18	1.82
Plant Height	1421.41	22.58	11.37
Spike Length	85.01	1.19	0.53
Grain Yield Wt. (Kg)	1.94	0.05	0.03
1000 Grain Wt. (Gm)	339.70	11.32	2.14

Note: * = Significant at 5% level ($p \leq 0.05$) ** = Highly significant at 1% level ($p \leq 0.01$)

ns = non-significant.

Phenological traits such as days to heading, anthesis, and maturity exhibited significant genetic differences, highlighting variability in heat escape mechanisms among genotypes. Plant height, spike length, thousand grain weight, and grain yield also showed significant variation, though the magnitude of variation was generally reduced compared to timely sown conditions due to stress imposed by higher temperatures during reproductive and grain-filling stages.

Overall, the ANOVA results confirm the existence of adequate genetic variability for key agronomic and yield-related traits under late sown conditions, validating the experimental design and supporting the scope for selection of heat-tolerant and stable genotypes.

Genotypic Performance Under Late Sown Conditions

Significant variability was observed among genotypes for grain yield and associated traits under late sown conditions (Table 2), reflecting differential responses to terminal heat stress.

Among the evaluated entries, Genotype 8033 (NINGA #1) recorded superior grain yield under late sowing, supported by relatively early heading, better ground cover, acceptable germination percentage, moderate spike length, and higher thousand grain weight, indicating its ability to maintain productivity under stress conditions.

Genotype 8031 exhibited good adaptability to late sowing, characterized by higher germination and ground cover, comparatively shorter crop duration, better grain weight, and stable yield performance under terminal heat stress.

Genotype 8035 also performed well, recording moderate to high grain yield with balanced phenology, longer spike length, and relatively higher thousand grain weight, suggesting its tolerance to delayed sowing.

Other notable genotypes included:

Genotype 8041 exhibited longer spike length along with stable yield performance, even under stress conditions, suggesting its potential adaptability to heat stress environments.

Genotype 8027 recorded moderate grain yield and showed fairly consistent performance across most of the studied traits, indicating balanced growth and productivity.

Genotype 8038 was characterized by early heading and comparatively better grain weight under heat stress, which may have contributed to its improved performance under late sown conditions.

Genotype 8037 demonstrated higher thousand-grain weight along with acceptable grain yield, reflecting efficient grain filling despite stress.

Among the local checks, LOK-1 maintained relatively higher yield under late sown conditions; however, it exhibited delayed phenological development. In contrast, TEJAS showed a moderate reduction in yield, along with shorter spike length and lower grain weight, indicating comparatively greater sensitivity to terminal heat stress.

Genetic Correlations in Late Sown

Genetic correlation analysis under late sown conditions revealed a strong positive association between germination percentage and ground cover ($r = 0.9999$, $p < 0.01$), indicating common genetic control over early establishment traits even under delayed sowing. Days to anthesis and days to maturity were positively and significantly correlated ($r = 0.6502$, $p < 0.01$), reflecting coordinated phenological development under stress.

Plant height exhibited significant negative correlations with early growth traits and phenological parameters, suggesting that relatively shorter plants tended to complete their life cycle earlier, an advantageous trait under terminal heat

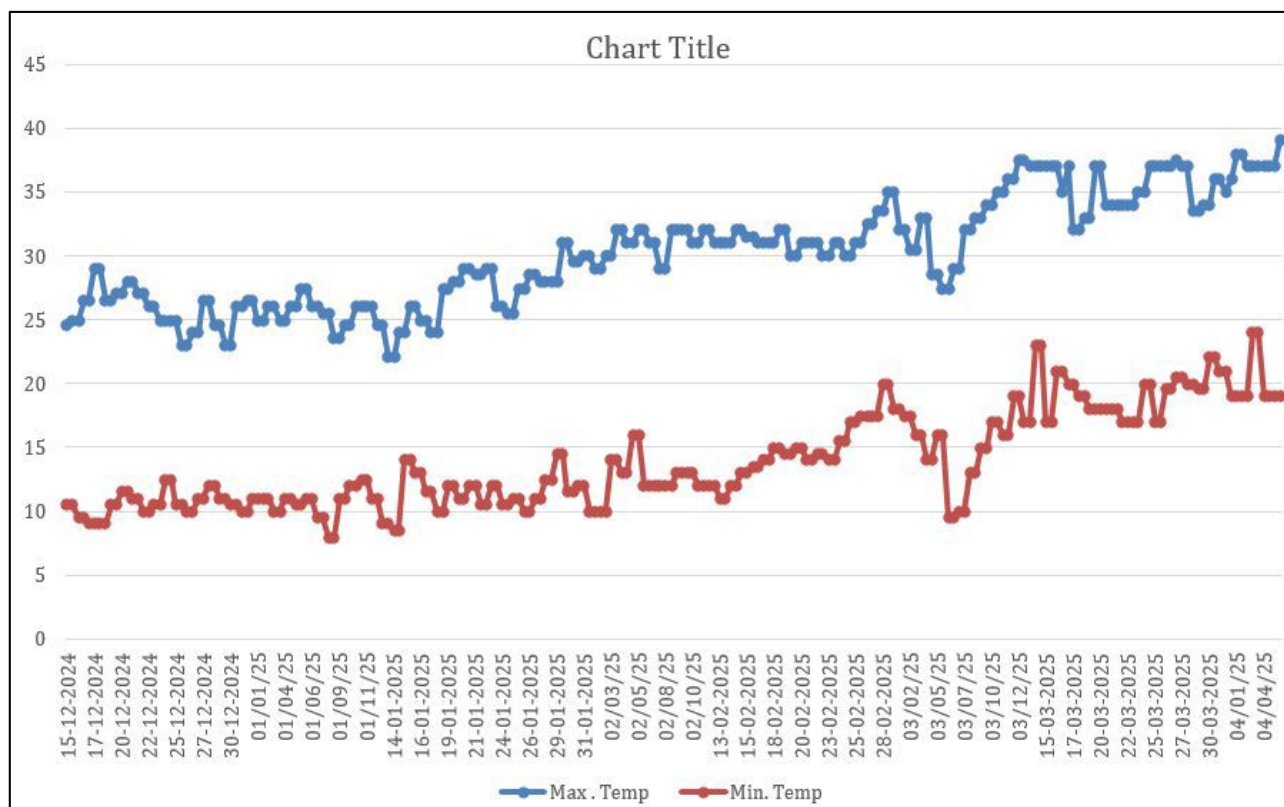
stress. Spike length showed a positive correlation with anthesis but a strong negative association with plant height, indicating independent genetic regulation of these traits.

Grain yield showed significant negative correlations with days to heading and days to maturity, emphasizing the importance of early flowering and early maturity for yield stabilization under late sown conditions. Thousand grain weight exhibited weak and mostly non-significant correlations with other traits, indicating its relative independence from phenological traits under heat stress environments.

Meteorological data during late sown condition (2024-25 season)

Meteorological conditions during the crop growth period play a crucial role in determining wheat performance, particularly under late sown environments. The late sown wheat crop (15 December 2024) was exposed to comparatively higher temperatures during the reproductive and grain-filling stages. Weather parameters recorded throughout the crop growth period indicated the prevalence of terminal heat stress, which adversely influenced crop duration, biomass accumulation, and grain development.

The exposure of wheat genotypes to elevated temperatures during critical growth stages provided an effective screening environment for identifying heat-tolerant genotypes. Variations in genotypic performance under these conditions highlight the importance of selecting genotypes with early phenology, better establishment, and stable yield attributes for cultivation under delayed sowing situations.



Graph 1: Meteorological data during Late sown condition (2024-25 season)

In Graph 1 Meteorological data during the crop growth period is a critical factor influencing wheat development, especially under stress or non-optimal conditions. The Late sown wheat crop (15th December 2024) was grown under standard climatic conditions, and the following weather

parameters were recorded at the experimental site during the entire crop growth duration.

Here is a more natural, smoothly written version suitable for the Materials and Methods or Agro-meteorological conditions section of your thesis:

Weather Conditions During Late Sown Crop

Sowing Period (Mid-December): During the time of sowing, the average maximum temperature ranged between 24-27 °C, while the minimum temperature varied from 9-12 °C. These conditions were moderately favourable for seed germination and crop establishment. However, due to the relatively shorter vegetative phase in late sowing, the crop had limited time for tiller development.

Vegetative to Booting Stage (Late December to January): In this phase, maximum temperatures ranged from 25-28 °C and minimum temperatures from 10-13 °C. The gradual rise in temperature promoted rapid plant growth, but the number of tillers was comparatively lower than in the timely sown crop. A prolonged dry spell prevailed during this period, making irrigation necessary to support proper crop development.

Heading and Anthesis Stage (Late January to Mid-February): A noticeable increase in temperature was recorded during this stage, with maximum temperatures rising to 30-32 °C and minimum temperatures to 14-16 °C. The crop experienced moderate to high heat stress, which likely reduced pollen viability and shortened the duration of anthesis.

Grain Filling to Maturity (March): During the grain filling stage, maximum temperatures peaked between 35-38 °C, while minimum temperatures ranged from 18-21 °C. The crop was subjected to terminal heat stress, which adversely affected grain filling, reduced 1000-grain weight, and ultimately influenced final yield.

Rainfall Pattern: No significant rainfall was received throughout the lifecycle of the late sown crop. To compensate for moisture deficiency and prevent water stress, four irrigations were applied at critical growth stages.

Genetic Parameters under Late Sown Condition

Under late sown conditions, high heritability estimates were recorded for early ground cover (0.96) and germination percentage (0.95), indicating that these early establishment traits remained largely under genetic control even under terminal heat stress. This suggests that effective improvement of early vigour traits through selection is feasible in stress-prone late sown environments. Plant height (0.34), days to anthesis (0.29), and days to heading (0.26) exhibited moderate heritability, implying that genetic improvement for these traits is possible, although environmental influence under late sowing necessitates careful and repeated selection across environments.

In contrast, days to maturity, spike length, grain yield, and 1000-grain weight showed low to negligible heritability under late sown conditions, reflecting the strong influence of high temperature stress during reproductive and grain-filling stages. The reduced heritability of yield and yield components indicates that their expression is highly environment-dependent under delayed sowing, limiting the effectiveness of direct selection for these traits.

Genotypic variance was highest for early ground cover (13.85) followed by plant height (4.27), indicating considerable genetic variability among genotypes for these traits even under stress conditions. The coefficient of variation (CV) remained within acceptable limits for most

traits (<5%), demonstrating satisfactory experimental precision despite the adverse environment. Genotypic effects were highly significant ($p<0.01$) for early ground cover and germination percentage, and significant ($p<0.05$) for plant height, confirming the presence of exploitable genetic variability under late sown conditions.

However, non-significant genotypic differences for grain yield and major yield-contributing traits suggest that terminal heat stress reduced phenotypic differentiation among genotypes, masking underlying genetic potential. This emphasizes the difficulty of improving grain yield directly under late sowing environments.

Overall, under late sown conditions, selection for early vigour and phenological traits, such as germination percentage, ground cover, and earlier heading or anthesis, offers greater potential for genetic improvement and stress adaptation. Yield enhancement under delayed sowing is likely to be more effective through indirect selection using stable and heritable component traits rather than direct selection for grain yield alone.

Conclusion

The study clearly demonstrates that delayed sowing and exposure to terminal heat stress during the reproductive phase markedly influence wheat productivity by shortening maturity duration and affecting plant height, grain size, and overall yield. Despite these constraints, the presence of significant genetic variability among the evaluated genotypes provides valuable opportunities for identifying and developing heat-tolerant and stable-performing wheat varieties under late sown conditions.

Key conclusions include

Genotypes 8033, 8031, and 8035 were top performers under late sown conditions, indicating their superior tolerance to terminal heat stress and suitability for delayed sowing environments.

Among the checks, Lok-1 outperformed Tejas under late sown conditions, reinforcing its wider adaptability and relative stability under stress environments.

This study identifies elite genotypes suited for late sown conditions, and the findings can directly support breeding programs aimed at improving heat stress tolerance, yield stability, and adaptability under changing climatic scenarios across diverse agro-climatic regions.

Future work involving molecular markers, physiological screening, and multi-location evaluation will further strengthen the utility of these genotypes for sustainable wheat improvement under stress-prone environments.

The late sown experiment identified several high-performing genotypes, notably 8033, 8031, and 8035, which combined better early establishment, favorable phenology, and stable grain traits under terminal heat stress. These results demonstrate significant potential for genetic improvement targeting both yield stability and stress adaptation in late sown wheat environments.

Authorship Contribution Statement

Dr. Chhavi Tiwari: Supervision, Project Administration, Validation, Writing-Review & Editing.

Shyam Vijay Vargiya: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing-Original Draft.

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Ethics Statement

This research was conducted in accordance with institutional, national, and international guidelines. The study did not involve human participants or animals; hence, ethical approval was not required. Standard agronomic practices were followed for the experimental trials, ensuring compliance with good research practices and biosafety measures.

References

1. Abasi M, Jaleel CA. Heat stress and respiration in wheat. *Environ Exp Bot.* 2024;182:104292.
2. AICRPW. All India Coordinated Research Project on Wheat and Barley: Technical Programme 2023-24. Indian Institute of Wheat and Barley Research (IIWBR), Karnal, India. 2023.
3. Asseng S, Foster I, Turner NC. The impact of temperature variability on wheat yields. *Field Crops Res.* 2013;154:1-11.
4. Baum M, Grando S, Backes G, Jahoor A, Sabbagh A, Ceccarelli S. QTLs for agronomic traits under Mediterranean environments. *Theor Appl Genet.* 2012;107:1215-1225.
5. Bergkamp B, *et al.* Chlorophyll degradation under heat stress. *J Exp Bot.* 2018;69(6):1295-1305.
6. Bhat JA, *et al.* Genomic selection for complex traits in plant breeding. *Front Genet.* 2016;7:221.
7. Bhusal N, Sharma BP, Ojha R. QTL mapping for heat tolerance in wheat: A review. *J Cereal Res.* 2017;9(2):84-95.
8. Bidinger FR, Musgrave RB, Fischer RA. Contribution of pre-anthesis assimilates to grain yield. *Nature.* 1977;270:431-433.
9. Bitá CE, Gerats T. Plant tolerance to high temperature stress. *Front Plant Sci.* 2013;4:273.
10. Blum A. *Plant Breeding for Stress Environments.* CRC Press; Boca Raton, USA. 1988.
11. Blum A, Tuberosa R. Genomics-based approaches for stress tolerance. *Trends Plant Sci.* 2011;15(9):548-558.
12. Cha J-Y, *et al.* Heat shock proteins in plant stress responses. *Trends Plant Sci.* 2020;25(8):742-756.
13. CIMMYT. *Bringing Together Farmers and Scientists for Sustainable Development.* CIMMYT, Mexico. 2005.
14. CIMMYT. *Heat-Tolerant Wheat Varieties for Stress-Prone Environments.* Annual Report, Mexico. 2020.
15. CIMMYT. *Annual Report 2021.* International Maize and Wheat Improvement Center. 2021.
16. Cochard H, Tyree MT. Hydraulic conductivity under heat stress. *J Exp Bot.* 2007;58(11):2597-2605.
17. Cohen S, Lurie S. Heat stress responses in plants. *Environ Exp Bot.* 2021;182:104292.
18. Cossani CM, Reynolds MP. Physiological traits for improving heat tolerance in wheat. *Plant Physiol.* 2012;160(4):1710-1718.
19. Dias A, Roychowdhury R. Heat stress effects on wheat yield. *Field Crops Res.* 2023;256:107893.
20. Dias A, Stone P. Grain quality responses to heat stress. *Field Crops Res.* 2008;107(2):139-146.
21. Directorate of Economics and Statistics. *Agricultural Statistics at a Glance.* Ministry of Agriculture & Farmers Welfare, Government of India. 2021.
22. Dixon J, Braun H-J, Kosina P. *Wheat Facts and Futures 2009.* CIMMYT & FAO. 2009.
23. Ehonen S, Kangasjärvi J. Reactive oxygen species and heat stress. *Front Plant Sci.* 2019;10:1-10.
24. Farooq M, Hussain M, Wahid A. Heat stress during reproductive stages in wheat. *Crit Rev Plant Sci.* 2011;30(6):491-507.
25. Feng Z, Ashraf M. Photosynthesis under heat stress. *Environ Exp Bot.* 2014;100:1-10.
26. Fischer RA, Maurer R. Drought resistance in wheat cultivars. *Aust J Agric Res.* 1978;29(5):897-912.
27. Gahlaut V, *et al.* Epigenetics in plant heat stress response. *Front Plant Sci.* 2020;11:815.
28. Gill SS, Tuteja N. Reactive oxygen species and antioxidants. *Environ Exp Bot.* 2015;91:1-12.
29. Gupta NK, Sharma A. Heat stress impacts on wheat seedlings. *Indian J Plant Physiol.* 2013;18(4):377-382.
30. ICAR-IIWBR. *Annual Report 2020-21.* Indian Institute of Wheat and Barley Research, Karnal. 2021.
31. IPCC. *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Cambridge University Press. 2007.
32. Johnson HW, Robinson HF, Comstock RE. Genetic variability estimates. *Agron J.* 1955;47:314-318.
33. Joshi AK, *et al.* *Wheat improvement in India.* Euphytica. 2007;157:431-446.
34. Khan AS, *et al.* Genetic variability under terminal heat stress in wheat. *Int J Agric Biol.* 2019;21(2):371-376.
35. Khanna-Chopra R, Sinha S. Leaf senescence under heat stress. *J Plant Biol.* 2012;55(1):1-10.
36. Kumar S, Singh R. Phenological responses of wheat to heat stress. *Indian J Agric Sci.* 2013;83(11):1150-1155.
37. Kumar S, *et al.* Physiological basis of yield under heat stress. *Euphytica.* 2019;215:179.