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RESEARCH ARTICLE

PERFORMANCE OF WHEAT (*TRITICUM AESTIVUM* L.) GENOTYPES UNDER TIMELY AND LATE SOWN CONDITIONS IN RESPONSE TO TERMINAL HEAT STRESS

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Abstract: This study, conducted during the Rabi seasons of 2021-2022 and 2022-2023 at the Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, aimed to assess the performance of 30 wheat genotypes under timely (November 18th) and late sowing conditions (December 28th), in response to heat stress using a Randomized Block Design (RBD) with three replications. Morphological parameters, such as days to heading, flowering, and maturity, grain filling duration, plant height, spike length, spikelets, effective tillers, grains per spike, 1000 grain weight, biomass, straw yield, harvest index, and grain yield, were recorded. The variance analysis of 14 morphological and yield-related parameters showed significant differences among 30 genotypes under timely and late sown conditions during both crop years which indicate a substantial scope for enhancement. The mean performance of the genotypes revealed wide variations in traits under both sowing conditions. The study demonstrated that timely sown conditions generally resulted in superior phenological development and improved grain yield, with certain genotypes exhibiting robust growth patterns. Conversely, late sowing, compounded by heat stress, led to variations in plant morphology, reduced tiller numbers, altered flowering times, and decreased yield across most genotypes. This research emphasizes the importance of ongoing efforts to develop heat-tolerant wheat genotypes to mitigate the adverse effects of heat stress, especially in regions prone to heat stress in general and at terminal stage in particular.

Keywords: Wheat, Heat stress, Morphological parameters, Grain yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the major cereal crops belonging to the *Poaceae (Gramineae)* family, contributing about 30% of world grain production and 50% of the world grain trade. Wheat is considered as a staple food in more than 40 countries of the world which provides basic calories and protein for 85% and 82% of the world population, respectively (Aktera *et al*., 2017). FAO estimated that the annual cereal production has to grow by almost one billion to feed the projected population of 9.1 billion by 2050. In order to meet the increased food requirement, an increase in crop production and productivity is the demand of the 21st century. Due to drastic changes in climate conditions in last 2-3 decades, major part of South Asia's rice-wheat zones are affected by heat stress, as defined by Fischer and Byerlee (1991), with mean daily temperatures above 17.5°C in the coolest month. The north-western plains of India are highly productive but more prone to high temperature stress caused by dry winds from the Thar Desert. On the other hand, wheat grown in the north-eastern plains is exposed to high temperature coupled with high humidity (Joshi *et al*., 2007a, b). Climate change and climate variability are emerging as major challenges to sustainable agriculture. The high inter and intra-seasonal variability in rainfall distribution, extreme temperature and rainfall events are causing crop damages and thus, farmers face huge losses each year. Significant decline in production is likely to be caused by shortening of growing period, which will have negative impact on reproduction and grain-filling particularly due to terminal-heat stress and decreased water availability (Agarwal and Rani, 2009). High temperature during grain development (grain-filling) is a major limitation to wheat production in many environments worldwide (Hays *et al*., 2007). Transitory or constantly high temperatures cause an array of morphological changes in plants, which affect plant growth and development and may lead to a drastic reduction in yield. A yield loss of 29% is expected by 2080 due to global warming in wheat. (Kumar *et al*., 2023a). Annual yield loss in wheat due to global warming is expected to be 7.7 billion dollars (Elahi *et al*., 2022) and by 2025, this would be around 18 billion dollars.

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Heat stress conditions induced during critical growth stages to simulate elevated temperatures, mirroring climatic scenarios that pose challenges to wheat cultivation (Kumar *et al*., 2023b). In current studies Morphological and yield-related parameters were extensively evaluated to identify the important traits associated with yield stability under terminal heat stress condition.

MATERIALS AND METHODOLOGY

The current investigation was carried out with Thirty wheat genotype were grown in timely and late sown condition during *Rabi* season 2021-22 and *Rabi* 2022-23 were obtained from IIWBR, Karnal (Table 1) and these genotypes were grown in Randomized Block Design (RBD) replicated thrice both sowings. Each genotype was sown in a 2-row with a row spacing of 22.5 cm at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110 (U.P.). Which is situated at 29º 01 latitudes in the North and 77º 45 longitudes in east and at altitude of 237 m above MSL, representing the North Western Plain Zone (NWPZ)? The soil of experimental field was fertile and sandy loam.

Weather Condition

The data of meteorological observations *viz*.- weekly distribution of rainfall, maximum and minimum temperature, relative humidity, wind velocity, mean evaporation rate and sunshine hours during the crop period of both years have been recorded from the SVPUA&T meteorological observatory in Modipuram, Meerut. It is clear that total rainfall during the crop period was 173.51 mm during 2021-22 and 160.70 mm during 2022-23. Minimum temperature 4.7 ºC was recorded in 3rd week in January month during 2021-22 (1st year crop) and 4.6 ºC in 1st week in January month during 2022-23 (2nd year crop) whereas, the Maximum temperature 41.6 ºC was recorded in 17th week in April month during 2022 (1st year crop) and 37.2 ºC in 16th week in April month during 2023 (2nd year crop), respectively. The maximum relative humidity was 92.6 % in 3rd week in January month during 2022 (1st year crop) and 97.9 % in 1std week in January month of 2023 (2nd year crop), respectively.

Table 1. Details of wheat genotypes used under the present study

Sr. no.	Genotype s	Pedigree	Origin	Recommend Zone	Main Characterstics
1.	HI8713	HD-4672/PDW-233	IARI, Regional Station, Indore	CZ	Irrigated, Timely Sown
2.	DBW14	RAJ3765/PBW343	IIWBR, Karnal	NEPZ	Irrigated, late Sown
3.	DBW90	HUW-468/WH-730	IIWBR, Karnal	NWPZ	Late sown, irrigated conditions
4.	DBW93	WHEAR/TUKURU//WHEAR	IIWBR, Karnal	PZ	Timely sown, restricted irrigated conditions
5.	HD2329	HD-2252/UP-262	IARI, New Delhi	NWPZ	irrigated, timely sown
6.	HD2864	K7537/HD2160/HD2278//L24/K4.14	IARI, New Delhi	CZ	Irrigated, late Sown
7.	HD2888	STAMPALLI/C-306//DL-153-2/HW-2003	IARI, New Delhi	NEPZ	rainfed, timely sown
8.	HD2932	KAUZ/STAR/HD 2643	IARI, New Delhi	NWPZ	Irrigated, late Sown
9.	HD2967	ALD/CUC//URES/HD2160/HD2278	IARI, New Delhi	NWPZ	Irrigated, Timely Sown
10.	HD2985	PBW 343/ PASTOR	IARI, New Delhi	NEPZ	Irrigated, late Sown
11.	HD3086	DBW14/HD2733//HUW468	IARI, New Delhi	NWPZ	Irrigated, Timely Sown
12.	HS375	BLUEBIRD/GALLO//CAJEME-71/3/TR.AE//KALYANSONA/BLUEBIRD	IARI Regional Station, Tutikandi, Shimla	NHZ	Irrigated/Rainfed, , Late Sown
13.	HS 490	HS-364/HPW-114//HS-240/HS-346	IARI, RRS, Shimla	NHZ	Irrigated, Timely Sown
14.	HS507	KAUZ/MYNA/VULTURE//BUCKBUCK/FLICKER/4/MILAN	IARI, RRS, Shimla	NHZ	Rain fed , timely sown
15.	HUW234	HUW-12*2/CPAN-1666//HUW-12	BHU, Varanasi	NEPZ	Irrigated, Medium Fertility, Late Sown
16.	PBW 343	ND/VG1944//KAL//BB/3/YACO's'/4/VEE5's'	PAU, Ludhiana	NWPZ/ NEPZ	Timely sown, irrigated, high
17.	PBW644	PBW-175/HD-2643	PAU, Ludhiana	NWPZ	Timely sown rainfed
18.	RAJ4083	PBW-343/UP-2442//WR-258/UP-2425	RAU, Durgapura	PZ	Late sown, irrigated
19.	WH1021	NY0T95/SONAK	CCS HAU, Hisar	NWPZ	Irrigated, late Sown
20.	WH1080	PRL/2*PASTOR	CCS HAU, Hisar	NWPZ	Irrigated/Rainfed, timely Sown
21.	WH1124	MUNIA/CHTO/AMSEL	CCS HAU, Hisar	NWPZ	Irrigated, late Sown
22.	WH147	E4870-C303/S339-PV18	CCS HAU, Hisar	NWPZ	Irrigated, ,Timely Sown
23.	DBW71	PRINIA/UP2425	IIWBR, Karnal	NWPZ	Irrigated, late Sown

24.	**WH1142**	CHENAEGILOPSSQUARROSA(TAUS)//FCT/3/2*WE AVER	CCS HAU, Hisar	NWPZ	restricted irrigation, timely sown
25.	**PBW723**	PBW343+Lr57/Yr40+Lr37/Yr17	PAU, Ludhiana	NWPZ	irrigated, timely sown
26.	**HD4728**	ALTAR84/STINT// SILVER 453/ SOMAT 3.1/4/ GREEN14/YAV10 /AUK	IARI, New Delhi	CZ	irrigated, timely sown
27.	**WB02**	DICOCCON CI9309/AE. SQUARROSA(409)/3/MILAN/S87230//BAV92/4/2*MILAN/S8732 0//BA	IIWBR, Karnal	NWPZ	Timely sown, irrigated conditions
28.	**PBW757**	PBW550/YR15/6*AVOCET/3/2*PBW550/4/PBW568+YR36/3*PBW550	PAU, Ludhiana	NWPZ	Irrigated, late Sown
29.	**HD3226**	GRACKLE/HD2894	IARI, New Delhi	NWPZ	Irrigated, Timely Sown
30.	**DBW303**	WBLL1*2/BRAMBLING/4/BABAX/LR42//BABAX*2/3/SHAMA*2/5/PBW343*2/KUKUNA*2//FRTL/PIFED	IIWBR, Karnal	NWPZ	Irrigated, Timely Sown

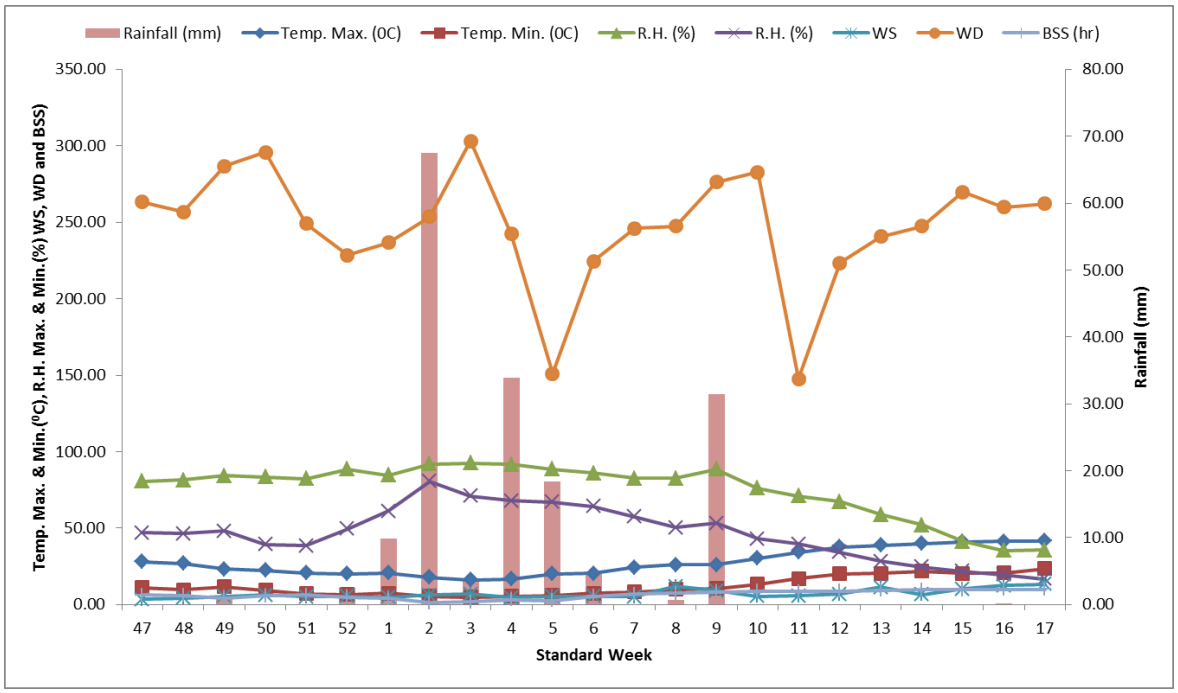

Fig. 1 Mean weekly Agro-meteorological data during the crop growing Rabi season (2021-22)

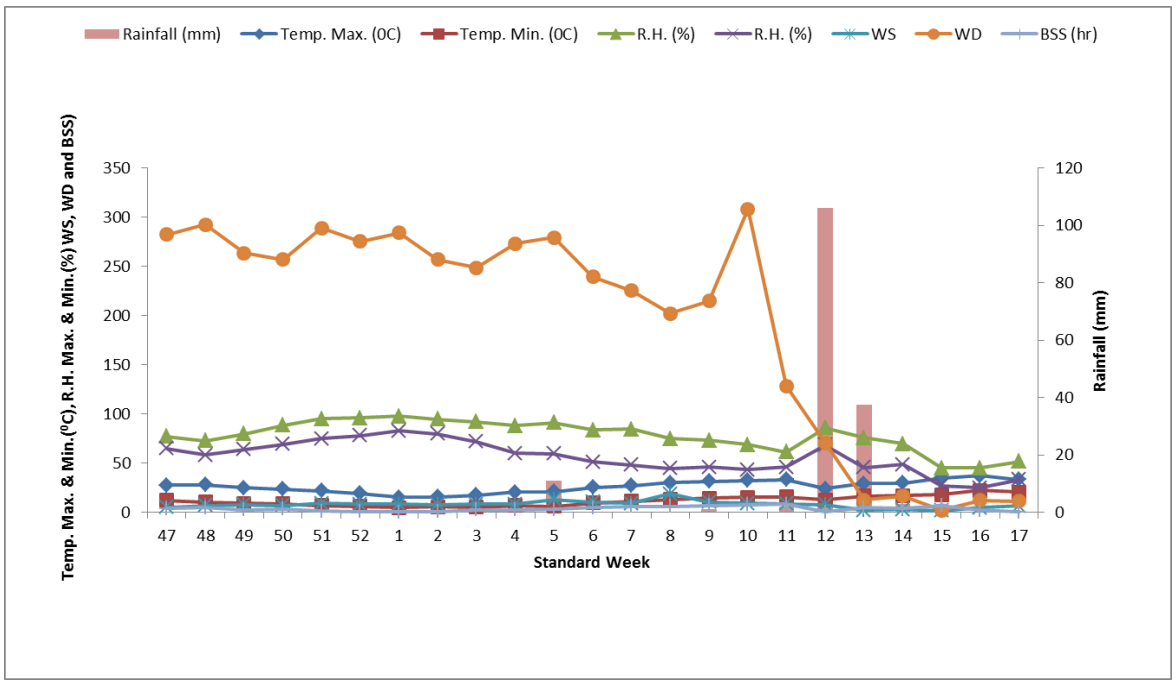

Fig. 2 Mean weekly Agro-meteorological data during the crop growing Rabi season (2022-23)

Observations recorded

Morphological attributes namely,days to 50 % heading, days to 50% flowering, days to maturity, grain filling period, plant height (cm), spike length with own (cm), number of spikelets per spike, number of grains per spike, number of effective tillers per plant, 1000 grain weight (g), biological yield per plant (g), grain yield per plant (g), straw yield per plant (g) and harvest index (%)were recorded. Statistical analysis was followed on the basis of replication wise mean values of the treatments.

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance of 14 different characters recorded on 30 wheat genotypes grown during both crop years under two environments viz., timely sown and late sown condition are presented in table 2, 3, 4 and 5 respectively. Analysis of variance revealed significant differences among the genotypes for all characters viz. days to 50% heading, days to 50% flowering, days to maturity, grain filling duration, plant height (cm), number of effective tillers per plant, spike length with owns (cm), number of spikelets per spike, number of grains per spike, 1000 grain weight (g), biological yield per plant (g), harvest index (%), grain yield per plant (g) and straw yield per plant (g). Analysis of variance revealed that there was significant variability present among genotypes for all the characters studied under timely and late sown condition during both crop years. Therefore, there is a good scope for enhancement of the genotypes by improving such characterstics. These results were in agreement with the findings with earlier report in wheat Arya *et al*., (2017), Yadav *et al*., (2021). Kumar *et al*., (2013), Sharma and Tandon (2007), Singh *et al*., (2015), Rangare *et al*., (2010), Kaddem *et al*., (2014) and Nukasani *et al*., (2013).

Mean performance of various traits under timely and late sown conditions during 2021-22 and 2022-2023.

The mean and range performance of 30 wheat genotype for fourteen characters under timely and late sowing during crop year (2021-22) is presented in table 6 and 7 and for crop year (2022-23) is presented in table 8 and 9 respectively. The genotype had very wide range of variation in mean performance of genotypes for all the 14 characters. These results were in agreement with the findings with earlier report in wheat Arya *et al*., (2017), Thapa *et al*., (2019), Prasad *et al*., (2021), Yadav *et al*., (2021), Gajghate, (2013), Singh *et al*., (2015) and Sarkar *et al*., (2021).

Days to heading

During 2021-22, Days to heading ranged from 89.00 (HD3086) to 101.00 (HI8713, HS507, HD4728) days with mean value of 95.98 under timely sown conditions and from 74.0 (HD3086) and 73.00 (WH1124) to 83.00 (RAJ4083) days with mean value of 78.87 days under late sown conditions while During 2022-23, Days to heading ranged from 86.00 (HD3086) to 98.00 (HD4728, HS507, HS375, HD2985 and HI8713) days with mean value of 93.20 days under timely sown conditions and from 73.00 (WH1124) to 90.00 (HD2967) days with mean value of 80.03 days under late sown conditions.

Days to flowering

During 2021-22, Days to flowering ranged from 92.00 (HD3086) to 105.00 (HI8713 and HD4728) days with mean value of 99.25 days under timely sown conditions and from 77.00 (WH1124) to 88.50 (RAJ4083) days with mean value of 82.54 days under late sown conditions while During 2022-23, Days to flowering ranged from 89.00 (HD3086) to 102.00 (HD4728, HD2985 and HI8713) days with mean value of 96.47 days under timely sown conditions and from 76.00 (WH1124) to 93.00 (HD2967) days with mean value of 83.33 days under late sown conditions.

Days to maturity

During 2021-22, Days to maturity ranged from 126.16 (PBW 343) to 140.16 (HI8713) days with mean value of 131.89 days under timely sown conditions and from 97.00 (DBW14) to 116.00 (PBW723) days with mean value of 107.57 days under late sown conditions while During 2022-23, Days to maturity ranged from 122.67 (PBW343) to 136.67 (HI8713) days with mean value of 128.70 days under timely sown conditions and from 95.00 (HD3226 and DBW14) to 113.00 (PBW723) days with mean value of 105.33 days under late sown conditions.

Grain filling duration

During 2021-22, Grain filling duration ranged from 29.30 (HD2985) to 46.5 (HD3086) days with mean value of 35.91 days under timely sown conditions and from18.5 (HD2985) to 39 (WH1080 and PBW723) days with mean value of 26.25 days under late sown conditions while During 2022-23, Grain filling duration ranged from 29.00 (HD3226) to 46.00 (HD3086) days with mean value of 35.50 days under timely sown conditions and from 18.00 (HD2985) to 33.00 (HD2868) days with mean value of 25.30 days under late sown conditions.

Plant height (cm)

During 2021-22, Plant height (cm) ranged from 89.20 (DBW14) to 130.20 (HD2868) cm with mean value of 101.08 cm under timely sown conditions and from 83.83 (DBW93) to 109.40 (HD2868) cm with mean value of 94.58 cm under late sown conditions while During 2022-23, Plant height (cm) ranged from 86.20 (DBW14) to 128.00 (HD2868) cm with mean value of 98.64 cm under timely sown conditions and from 80.23 (DBW93) to 107.60 (HD2868) cm with mean value of 92.31 cm under

late sown conditions.

Spike length

During 2021-22, Spike length ranged from 15.33(DBW303) to 22.15 (HD4728) cm with mean value of 18.21 cm under timely sown conditions and from 12.87 (DBW303) to 20.81 (HI8713) cm with mean value of 15.41 cm under late sown conditions while During 2022-23, Spike length ranged from 14.75 (DBW303) to 21.50 (HD4728) cm with mean value of 17.59 cm under timely sown conditions and from 12.40 (DBW303), (HD2967) and (DBW93) to 20.25 (HI8713) cm with mean value of 14.89 cm under late sown conditions.

Spikelets

During 2021-22, Spikelets ranged from 16.19 (HD2868) to 25.25 (DBW90) with mean value of 22.00 under timely sown conditions and from 14.60 (HD2868) to 22.54 (HS375) with mean value of 18.90 under late sown conditions while During 2022-23, Spikelets ranged from 15.39 (HD2868 and DBW303) to 24.60 (DBW90) with mean value of 21.27 under timely sown conditions and from 14.00 (HD2868) to 22.00 (HS375) with mean value of 18.34 under late sown conditions.

Numbers of effective tillers / plant

During 2021-22, Numbers of effective tillers / plant ranged from 25.86 (WH1142) to 44.68 (WH1124) with mean value of 33.14 under timely sown conditions and from 18.24 (DBW93) to 33.29 (WH1080) with mean value of 24.38 under late sown conditions while During 2022-23, Numbers of effective tillers / plant ranged from 22.54 (HD2868) to 49.08 (WH1124) with mean value of 30.86 under timely sown conditions and from 16.44 (DBW93) to 31.11 (PBW 343) with mean value of 22.94 under late sown conditions.

Numbers of grains per spike

During 2021-22, Numbers of grains per spike ranged from 50.71(WH1142) to 76.60 (HI8713) with mean value of 66.75 under timely sown conditions and from 34.19 (DBW14) to 63.37 (HI8713) with mean value of 47.02 under late sown conditions while During 2022-23, Numbers of grains per spike ranged from 47.20 (WH1124) to 72.10 (HI8713) with mean value of 62.59 under timely sown conditions and from 32.20 (DBW14) to 60.40 (HI8713) with mean value of 44.20 under late sown conditions.

1000 grain weight (g)

During 2021-22, 1000 grain weight (g) ranged from 29.52 (WH1142) to 51.92 (HD4728) grams with mean value of 43.79 grams under timely sown conditions and from 25.74 (WH1124) to 40.95 (DBW90) grams with mean value of 34.67 grams under late sown conditions while During 2022-23, 1000 grain weight (g) ranged from 28.32 (WH1142) to 49.80 (HD4728) grams with mean value of 41.91 grams under timely sown conditions and from 24.70 (WH1124) to 39.30 (DBW90) grams with mean value of 33.34 grams under late sown conditions.

Biomass (g/plant)

During 2021-22, Biomass (g/plant) ranged from 140.71 (RAJ4083) to 178.06 (HD3226) with mean value of 155.01 under timely sown conditions and from 96.96 (DBW303) to 138.52 (WH1124) with mean value of 113.27 under late sown conditions while During 2022-23, Biomass (g/plant) ranged from 114.00 (RAJ4083) to 172.67 (DBW90) with mean value of 143.53 under timely sown conditions and from 87.00 (HD3086) to 133.82 (DBW90) with mean value of 105.82 under late sown conditions.

Straw yield (g/plant)

During 2021-22, Straw yield (g/plant) ranged from 53.82 (HD2967) to 118.22 (DBW90) with mean value of 84.80 under timely sown conditions and from 68.31 (DBW303) to 87.37 (WH1080) with mean value of 73.13 under late sown conditions while During 2022-23, Straw yield (g/plant) ranged from 53.82 (HD2967) to 115.89 (DBW90) with mean value of 84.79 under timely sown conditions and from 53.58 (RAJ4083) to 95.03 (HS375) with mean value of 73.65 under late sown conditions.

Harvest index (%)

During 2021-22, Harvest index (%) ranged from 37.81 (PBW723) to 43.89 (HD2329) % with mean value of 40.75 % under timely sown conditions and from 24.15 (WH1080) to 42.30 (WH1124) % with mean value of 32.63 % under late sown conditions while During 2022-23, Harvest index (%) ranged from 32.89 (DBW90) to 56.60 (HD2967) % with mean value of 41.19 % under timely sown conditions and from 22.42 (HD4728) to 40.79 (HUW234) % with mean value of 30.31 % under late sown conditions.

Grain yield (g/plant)

During 2021-22, Grain yield (g/plant) ranged from 55.56 (HD2864) to 75.43 (HD2967) with mean value of 63.21 under timely sown conditions and from 27.82 (WH1080) to 58.59 (WH1124) with mean value of 37.35 under late sown conditions while During 2022-23, Grain yield (g/plant) ranged from 52.95 (WH114) to 71.23 (HD3226) with mean value of 58.75 under timely sown conditions and from 23.76 (DBW303) to 52.45 (WH1124) with mean value of 32.22 under late sown conditions.

CONCLUSION

The study carried out at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology in Meerut. Thirty wheat genotypes obtained from IIWBR, Karnal, were subjected to a Randomized Block Design (RBD) with three replications under both timely and late sown conditions during crop year 2021-22 and 2022-23. Morphological attributes, encompassing critical growth stages such as days to heading, flowering, and maturity, along with plant height, spike length, spikelets, effective tillers, grains per spike, 1000 grain weight, biomass, straw yield, harvest index, and grain yield, were meticulously recorded for each genotype. The analysis of variance for the recorded

characters revealed significant differences among the genotypes, indicates that substantial variability exists among these genotypes and provides an opportunity for enhancement of these traits. The mean performance of the 30 wheat genotypes exhibited a wide range of variations across all the recorded characters under both timely and late sown conditions during the both crop years. The variations in these characters provided a comprehensive understanding of the responses of different genotypes to diverse environmental conditions. The findings from this study contribute to the growing body of knowledge on wheat genotypes' adaptability and performance under heat stress conditions induced by changes in weather patterns. These insights are crucial for developing strategies to mitigate the adverse effects of heat stress on wheat cultivation.

Table 2. Mean sum squares genotypes for timely sown condition during year 2021-2022

Source of variation	DF	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
Repl	2	3.56	3.59	4.00	6.65	1.20	0.15	0.23	0.21	2.17	0.80	8.97	1.59	0.55	1.54
Treatment	29	248.13**	41.50**	46.90**	34.14**	38.62**	6.68**	10.60**	47.61**	128.74**	77.15**	257.22**	505.37**	8.98**	82.92**
Error	58	9.46	8.47	9.05	15.95	0.67	0.31	0.45	1.03	4.11	1.78	22.14	6.79	1.53	3.69
Total	89	87.10	19.12	21.27	21.67	13.05	2.38	3.75	16.19	44.68	26.32	98.44	169.13	3.93	29.46

Table 3. Mean sum squares genotypes for late sown condition during year 2021-2022

Source of variation	DF	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
Repl	2	2.97	2.30	2.50	4.07	0.07	0.11	0.20	0.10	1.00	0.44	3.95	1.73	0.33	0.35
Treatment	29	97.79**	58.52**	29.78**	106.90**	49.74**	9.48**	8.08**	54.06**	163.84**	54.15**	377.10**	258.63**	69.51**	235.36**
Error	58	8.25	6.16	5.87	10.66	0.48	0.22	0.33	0.57	2.07	1.12	11.93	4.99	1.00	1.36
Total	89	37.31	23.13	13.59	41.87	16.52	3.23	2.85	17.99	54.76	18.38	130.74	87.57	23.31	77.58

Table 4. Mean sum squares genotypes for timely sown condition during year 2022-2023

Source of variation	DF	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
Repl	2	3.52	3.42	3.64	3.03	1.07	0.15	0.23	0.13	1.98	0.76	1.66	3.45	0.43	1.32
Treatment	29	248.30**	40.84**	46.29**	32.05**	45.51**	6.60**	10.65**	126.38**	118.62**	70.81**	502.19**	491.72**	61.83**	73.08**
Error	58	9.01	7.98	8.55	5.57	0.34	0.29	0.42	0.92	3.62	1.63	16.12	5.68	0.24	3.19
Total	89	86.86	18.59	20.74	14.14	15.07	2.34	3.75	41.78	41.05	24.15	174.18	164.00	20.31	25.92

Table 5. Mean sum squares genotypes for late sown condition during year 2022-2023

Source of variation	DF	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
Repl	2	2.97	2.29	2.45	3.25	0.02	0.10	0.27	0.10	1.06	0.45	0.72	1.73	0.03	0.22
Treatment	29	108.50**	57.30**	56.62**	127.53**	46.33**	9.36**	7.75**	51.24**	182.85**	50.26**	516.75**	258.63**	97.08**	190.11**
Error	58	7.86	5.89	6.38	10.35	0.35	0.21	0.31	0.50	1.84	1.04	6.40	4.99	0.47	1.02
Total	89	40.54	22.56	22.67	48.37	15.32	3.19	2.73	17.02	60.80	17.06	172.57	87.57	31.94	62.62

Table 6. Mean performance of timely sown condition during Year 2021-2022

Var	Genotypes	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
1	HI8713	101.1	101	105	140.16	39.16	21.65	22.92	33.28	76.6	41.96	147.54	73.77	39.64	58.48
2	DBW14	89.2	92.5	95.5	129.46	36.96	17.96	21.65	29.92	66.9	44.49	160.95	91.88	38.66	62.22
3	DBW90	101.38	89.5	92.5	126.8	37.3	19.5	25.25	31	57.38	43.3	148.1	118.22	40.25	59.61
4	DBW93	90.2	91	94	128.83	37.83	17.88	23.06	27.94	73.78	49.26	159.03	85.11	42.95	68.3
5	HD2329	90.4	91	94	130.5	39.5	17.15	21	37.96	71.69	47.17	150.5	90.78	43.89	66.05
6	HD2864	96.9	91.5	94.5	131.46	39.96	17.71	22.43	31.32	66.07	44.84	141	104.29	39.4	55.56
7	HD2868	130.2	91	94	129.5	38.5	18.74	16.19	32.77	56.85	40.55	157.87	70.23	38.25	60.39
8	HD2932	98.8	98.5	102.5	134.13	35.63	16.76	22.25	35.64	61.02	42.44	161	86.23	42.34	68.16
9	HD2967	97.2	97	100	130.5	33.5	17.58	20.14	36.03	54.13	49.66	174.24	53.82	43.29	75.43
10	HD2985	104.7	100.5	104.5	129.8	29.3	18.38	21.05	32.4	69.73	40.34	148.84	84.57	38.64	57.51
11	HD3086	99.78	89	92	135.5	46.5	18.85	21.68	34.7	71.27	41.7	148.2	67.99	43.2	64.02
12	HS375	108	100.5	103.5	134.13	33.63	19.98	25.05	28.84	74.9	42.2	153.07	99.14	39.06	59.79
13	HS 490	127	99	101	135.5	36.5	20.75	22.4	33.45	71.48	48.83	157.07	103.58	39.73	62.4
14	HS507	94	101	104	137.16	36.16	17.94	23	31.2	67.06	49.26	163.32	90.73	39.63	64.73
15	HUW234	99.8	96.5	100.5	129.8	33.3	18.1	20.65	32.72	66.07	46.41	163.1	77.02	40.63	66.26
16	PBW 343	94.92	96	99	126.16	30.16	16.59	19.8	31.21	63.95	45.37	150.43	83.13	40.48	60.9
17	PBW644	106.6	97	99	133.16	36.16	18.54	23.8	32.54	66.04	40.92	159.77	88.17	40.55	64.79
18	RAJ4083	100.6	97.5	100.5	128.13	30.63	18.21	20.15	38.88	57.37	47.37	140.71	59.77	42.11	59.26
19	WH1021	107.6	97.5	100.5	131.13	33.63	17.71	23.05	33.48	69.22	48.48	156.13	77.77	41.03	64.06
20	WH1080	101	97	101	135.5	38.5	18.25	21.28	38.38	72.31	42.72	157.29	84.77	38.2	60.09
21	WH1124	102.4	93.5	96.5	133.8	40.3	16.44	19.65	44.68	50.71	47.4	169.42	92.14	43.13	73.08
22	WH147	103.4	95	99	131.83	36.83	18.85	21.4	32.7	63.8	36.17	143.65	89.72	40.85	58.68
23	DBW71	93.7	93.5	96.5	126.46	32.96	17.41	20.65	27.92	66.91	45.27	149.66	84.21	42.69	63.89
24	WH1142	99.54	97	100	135.16	38.16	19.23	25.2	25.86	74.11	29.52	141.18	87.05	39.83	56.23
25	PBW723	101.48	98	101	131.16	33.16	17.57	21.8	36.87	72.58	33.61	148.04	78.11	37.81	55.98
26	HD4728	106.1	101	105	136.83	35.83	22.15	24.2	31.2	72.21	51.92	161.92	97.87	42.33	68.54
27	WB02	96.6	99	103	132.16	33.16	16.85	22	33.86	71.1	50.3	157.54	78.04	41.28	65.03
28	PBW757	93.3	96.5	100.5	131.8	35.3	17.17	22.34	29.16	68.62	40.14	150.36	84.77	41.09	61.78
29	HD3226	103.6	100	104	129.5	29.5	17.07	23	38.45	67.93	43.03	178.06	80.14	42.1	74.96
30	DBW303	93	91.5	94.5	130.8	39.3	15.33	22.99	29.84	60.81	39.09	152.36	81.11	39.54	60.25
	Mean	**101.08**	**95.98**	**99.25**	**131.89**	**35.91**	**18.21**	**22.00**	**33.14**	**66.75**	**43.79**	**155.01**	**84.80**	**40.75**	**63.21**
	Min	89.2	89	92	126.16	29.3	15.33	16.19	25.86	50.71	29.52	140.71	53.82	37.81	55.56
	Max	130.2	101	105	140.16	46.5	22.15	25.25	44.68	76.6	51.92	178.06	118.22	43.89	75.43
	SE(d) ±	2.51	2.38	2.46	3.26	0.67	0.45	0.55	0.83	1.66	1.09	3.84	2.13	1.01	1.57
	C.D. at 5%	5.04	4.77	4.93	6.54	1.34	0.91	1.09	1.66	3.32	2.19	7.71	4.27	2.03	3.15
	C.V. (%)	3.04	3.03	3.03	3.03	2.52	3.04	3.03	3.06	3.04	3.05	3.04	3.07	3.04	3.04

Table 7. Mean performance of late sown condition during Year 2021-2022

Var	Genotypes	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
1	HI8713	95.4	83	85	113	30	20.81	20.1	26.23	63.37	35.56	102.93	72.64	29.43	30.29
2	DBW14	85.4	77.5	80	97	19.5	14.47	18.64	21.09	34.19	37.81	135.24	86.01	36.4	49.23
3	DBW90	93.38	76	79.5	107	31	15.47	18.84	21.69	38.77	40.95	118.79	76.23	35.83	42.56
4	DBW93	83.83	80.8	84.67	113	32.2	12.96	19.2	18.24	46.63	39.71	109.22	75.44	30.93	33.78
5	HD2329	87.56	76	81	110	34	15.56	18.4	28.94	45.13	33.11	101.13	72.17	28.64	28.96
6	HD2864	91.83	75.5	78	100	24.5	15.67	16.14	23.76	45.03	38.97	114.4	72.98	36.21	41.42
7	HD2868	109.4	78	81	100	22	16.76	14.6	18.41	49.7	38.72	105	74.77	28.79	30.23

8	HD2932	87.88	81	86.5	114	33	14.47	17.04	28.62	39.61	29.7	126.2	77.67	38.45	48.53
9	HD2967	92.5	76	79.9	110	34	12.96	18.85	21.48	42.49	35.4	110.48	72.25	34.6	38.23
10	HD2985	98.4	81.5	85	100	18.5	14.07	18.74	25.56	52.32	31.68	112.54	72.25	35.8	40.29
11	HD3086	100.4	74	78	108	34	16.16	20.1	27.62	35.41	31.66	108.34	78.06	27.95	30.28
12	HS375	99	82	86	109	27	17.67	22.54	18.4	46.75	28.66	123.61	79.38	35.78	44.23
13	HS 490	98.8	77	81	111	34	18.16	20.8	23.28	39.35	31.24	117.1	84.28	28.03	32.82
14	HS507	90.2	82	84.3	111	29	14.76	20.6	21.25	44.58	39.71	108.58	73.16	32.62	35.42
15	HUW234	96.4	78	81	104	26	15.27	17.94	27.31	46.75	33.87	134.21	81.98	38.92	52.23
16	PBW 343	87.8	77	81	101	24	14.96	18.1	30.36	40.61	27.4	99.42	70.45	29.14	28.97
17	PBW644	99.88	82	85	109	27	13.76	18.6	26.01	41.42	36.23	114.26	82.68	27.64	31.58
18	RAJ4083	89.04	83	88.5	112	29	15.17	18.54	23.91	48.99	32.41	116.2	73.4	36.83	42.8
19	WH1021	100.32	79	81	99	20	16.27	19.54	27.03	40.65	35.32	127.58	78.35	38.59	49.23
20	WH1080	96.2	76	81	115	39	14.76	16.5	33.29	46.18	37.26	115.19	87.37	24.15	27.82
21	WH1124	98.83	75	77	108	33	13.07	17.84	31.63	39.61	25.74	138.52	79.93	42.3	58.59
22	WH147	98.2	79	84	112	33	16.76	19	27.37	51.98	28.86	99.64	70.65	29.09	28.99
23	DBW71	91.16	80	86.5	112	32	14.27	18.74	22.14	44.99	39.08	121.93	73.17	39.99	48.76
24	WH1142	97.48	80	82	110	30	17.76	21.6	18.99	58.82	33.71	107.74	77.45	28.11	30.29
25	PBW723	94.8	77	82.4	116	39	13.84	19.8	29.54	59.74	30	104.13	73.87	29.06	30.26
26	HD4728	98.4	81	84	112	31	16.98	19	22.16	50.01	38.67	102.42	70.21	31.45	32.21
27	WB02	96.1	82	85	102	20	16.46	21.4	18.99	55.14	40.38	106.45	77.78	26.93	28.67
28	PBW757	86.96	80.5	83	102	21.5	14.67	18.14	21.78	57.74	36.71	118.27	72.41	38.78	45.86
29	HD3226	100.3	77	82	98	21	15.56	19.6	26.38	55.3	38.51	101.77	72.35	28.91	29.42
30	DBW303	91.4	79.5	83	104	24.5	12.87	17.94	19.8	49.27	33.03	96.96	68.31	29.55	28.65
	Mean	**94.58**	**78.87**	**82.54**	**107.57**	**26.25**	**15.41**	**18.9**	**24.38**	**47.02**	**34.67**	**113.27**	**73.13**	**32.63**	**37.35**
	Min	83.83	74	77	97	18.5	12.87	14.6	18.24	34.19	25.74	96.96	68.31	24.15	27.82
	Max	109.4	83	88.5	116	39	20.81	22.54	33.29	63.37	40.95	138.52	87.37	42.3	58.59
	SE(d) ±	2.35	1.93	1.96	2.67	0.56	0.38	0.47	0.61	1.18	0.86	2.82	1.82	0.82	0.95
	C.D. at 5%	4.71	3.87	3.94	5.35	1.13	0.77	0.94	1.23	2.36	1.74	5.66	3.66	1.64	1.91
	C.V. (%)	3.04	3.04	3.03	3.04	2.63	3.04	3.03	3.09	3.06	3.05	3.05	3.06	3.07	3.12

Table 8. Mean performance of timely sown condition during Year 2022-2023

Var	**Genotypes**	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
1	HI8713	98.9	98	102	136.67	38.67	21	22.12	28.27	72.1	40.25	128.4	74.17	42.24	54.23
2	DBW14	86.2	90	93	126.67	36.67	17.38	21	25.12	62.59	42.45	152.92	92.8	39.31	60.12
3	DBW90	98.4	87	90	124	37	18.92	24.6	26.17	53.54	41.32	172.67	115.89	32.89	56.78
4	DBW93	88	88	91	125.33	37.33	17.23	22.26	24.08	69.4	47.25	149.88	86.99	41.96	62.89
5	HD2329	88.2	88	91	127	39	16.5	20.2	37.01	67.4	45.25	152.9	90.78	40.63	62.12
6	HD2864	93.9	89	92	128.67	39.67	17.13	21.78	31.13	61.8	42.79	158	104.29	33.99	53.71
7	HD2868	128	88	91	126	38	18.09	15.39	22.54	53.2	38.9	124.12	70.23	43.42	53.89
8	HD2932	95.8	96	100	131.33	35.33	16.18	21.6	35.42	57	40.5	149.47	86.23	42.31	63.24
9	HD2967	95	94	97	127	33	16.93	19.34	25.04	50.6	47.64	124	53.82	56.6	70.18
10	HD2985	101.7	98	102	127	29	17.8	20.4	32.2	65.28	38.49	140.45	84.57	39.79	55.88
11	HD3086	97.58	86	89	132	46	18.2	20.88	33.5	67	40	128.22	67.99	46.97	60.23
12	HS375	105	98	101	131.33	33.33	19.4	24.4	24.08	70.2	40.27	156.04	101.18	35.15	54.86
13	HS 490	124.8	96	98	132	36	20.1	21.6	30.33	67.2	46.84	158.55	100.13	36.86	58.42
14	HS507	91.8	98	101	133.67	35.67	17.29	22.2	27.48	62.97	47.25	152	90.73	40.31	61.27

15	HUW234	96.8	94	98	127	33	17.52	20	35.93	61.8	44.28	138	77.02	44.19	60.98
16	PBW 343	92.72	93	96	122.67	29.67	15.94	19	40.16	60	43.52	140	83.13	40.62	56.87
17	PBW644	104.4	94	96	129.67	35.67	17.89	23	31.71	62	39.25	148	88.17	40.43	59.83
18	RAJ4083	97.6	95	98	125.33	30.33	17.63	19.5	38.05	53.54	45.2	114	59.77	47.57	54.23
19	WH1021	104.6	95	98	128.33	33.33	17.13	22.4	32.76	64.8	46.26	138	77.77	43.64	60.23
20	WH1080	98.8	94	98	132	38	17.6	20.48	42.27	68	40.98	139	84.77	39.01	54.23
21	WH1124	99.4	91	94	131	40	15.86	19	49.08	47.2	45.23	160	92.14	42.41	67.86
22	WH147	101.2	92	96	128.33	36.33	18.2	20.6	34.14	59.85	34.7	143	89.72	37.26	53.28
23	DBW71	90.7	91	94	123.67	32.67	16.83	20	25.6	62.6	43.2	141	84.21	40.28	56.79
24	WH1142	97.34	94	97	131.67	37.67	18.58	24.4	23.47	69.72	28.32	140	87.05	37.82	52.95
25	PBW723	99.28	95	98	127.67	32.67	16.92	21	36.8	68.25	32.24	132	78.11	40.83	53.89
26	HD4728	103.9	98	102	133.33	35.33	21.5	23.4	28.14	67.9	49.8	160	97.87	38.83	62.13
27	WB02	94.4	96	100	128.67	32.67	16.2	21.2	23.03	66.84	48.25	137	78.04	43.04	58.96
28	PBW757	90.3	94	98	129	35	16.59	21.69	28.27	64.23	38.3	142	84.77	40.3	57.23
29	HD3226	101.4	97	101	126	29	16.42	22.2	30.36	63.8	41.28	151.37	80.14	47.06	71.23
30	DBW303	93	89	92	128	39	14.75	22.34	23.68	56.8	37.3	135	81.11	39.92	53.89
	Mean	**98.64**	**93.20**	**96.47**	**128.70**	**35.50**	**17.59**	**21.27**	**30.86**	**62.59**	**41.91**	**143.53**	**84.79**	**41.19**	**58.75**
	Min	86.2	86	89	122.67	29	14.75	15.39	22.54	47.2	28.32	114	53.82	32.89	52.95
	Max	128	98	102	136.67	46	21.5	24.6	49.08	72.1	49.8	172.67	115.89	56.6	71.23
	SE(d) ±	2.45	2.31	2.39	1.93	0.47	0.44	0.53	0.78	1.55	1.04	3.28	1.95	0.4	1.46
	C.D. at 5%	4.92	4.63	4.79	3.87	0.95	0.88	1.06	1.57	3.12	2.09	6.58	3.91	0.8	2.93
	C.V. (%)	3.04	3.03	3.03	1.83	1.63	3.04	3.03	3.11	3.04	3.05	2.8	2.81	1.18	3.04

Table 9. Mean performance of late sown condition during Year 2022-2023

Var	**Genotypes**	Plant height (cm)	Days to 50% Heading	Days to 50 % Flowering	Days to maturity	Grain filling Duration	Spike length	Spikelets	Numbers of effective tillers / plant	Numbers of grains per spike	1000 grain weight (g)	Biomass (g/plant)	Straw yield (g/plant)	Harvest index (%)	Grain yield (g/plant)
1	HI8713	93.6	81	84	110	29	20.25	19.5	22.01	60.4	34.26	95.65	71.33	25.43	24.32
2	DBW14	82.8	76	79	95	19	14	18.1	19.14	32.2	36.29	121.7	76.33	37.28	45.37
3	DBW90	90.78	78	81	105	27	15	18.3	20.3	36.6	39.3	133.82	94.87	29.11	38.95
4	DBW93	80.23	88	91	108	20	12.4	18.6	16.44	41.23	38.26	104.19	74.56	28.44	29.63
5	HD2329	83.96	79	82	107	28	15	17.8	27.07	34.8	31.9	95	68.77	27.61	26.23
6	HD2864	89.23	74	77	98	24	15.2	15.6	24.77	32.6	37.4	129.78	90.55	30.24	39.23
7	HD2868	107.6	79	83	112	33	16.2	14	17.58	47.2	37.3	89.49	64.21	28.25	25.28
8	HD2932	85.28	85	89	112	27	14	16.5	27.35	37.4	28.5	113.84	70.98	37.65	42.86
9	HD2967	90.7	90	93	110	20	12.4	18.25	20.51	40.23	34.1	91.91	57.68	37.24	34.23
10	HD2985	95.8	80	85	98	18	13.6	18.2	24.42	49.6	30.4	113.33	76.1	32.86	37.23
11	HD3086	98.6	76	79	105	29	15.6	19.5	26.38	33.4	30.5	87	58.48	32.78	28.52
12	HS375	96.4	81	86	107	26	17.2	22	17.58	44.25	27.5	129.26	95.03	26.49	34.23
13	HS 490	97	79	83	108	29	17.6	20.2	22.47	37.2	30.1	111.23	84.7	23.85	26.53
14	HS507	88.4	80	83	108	28	14.2	20	21.77	52.23	38.26	103.52	74.29	28.24	29.23
15	HUW234	93.8	76	79	105	29	14.8	17.4	28	44.25	32.5	106	62.76	40.79	43.24
16	PBW 343	86	75	78	98	23	14.4	17.5	31.11	38.42	26.4	95	69.72	26.61	25.28
17	PBW644	98.08	80	82	106	26	13.2	18	25.92	39.2	34.9	104.53	76.68	26.64	27.85
18	RAJ4083	86.44	87	89	108	21	14.7	18	22.01	46.4	31.1	90	53.58	40.47	36.42
19	WH1021	97.72	77	80	97	20	15.8	19	24.88	38.4	33.9	111.77	67.6	39.52	44.17
20	WH1080	94.4	85	87	111	26	14.2	16.5	29.98	43.8	35.9	100.7	75.84	24.69	24.86
21	WH1124	96.23	73	76	106	33	12.6	17.3	28.11	37.4	24.7	131.45	79	39.93	52.45
22	WH147	96.4	82	85	109	27	16.2	18.4	25.3	49.4	27.8	103	78.11	24.17	24.89
23	DBW71	88.56	85	88	112	27	13.8	18.2	20.72	42.56	37.5	106	67.76	36.08	38.24
24	WH1142	95.68	78	82	107	29	17.2	21	17.76	56	32.48	100	74.08	25.92	25.92
25	PBW723	93	86	90	113	27	13.28	19.2	27.63	56.89	28.9	95	69.22	27.14	25.78
26	HD4728	96.6	79	82	109	30	16.42	18.4	20.09	47.5	37.25	112.35	87.17	22.42	25.18
27	WB02	94.3	80	84	99	19	15.9	20.8	16.55	52.45	38.9	98	72.16	26.37	25.84
28	PBW757	84.36	79	83	100	21	14.2	17.6	20.23	54.8	35.23	113.12	76.89	32.03	36.23
29	HD3226	98.5	75	79	95	20	15	19	22.99	52.6	37.1	95.84	70.98	25.94	24.86
30	DBW303	88.8	78	81	102	24	12.4	17.4	19.14	46.67	31.7	94	70.24	25.28	23.76

	Mean	**92.31**	**80.03**	**83.33**	**105.33**	**25.30**	**14.89**	**18.34**	**22.94**	**44.20**	**33.34**	**105.82**	**73.65**	**30.31**	**32.22**
	Min	80.23	73	76	95	18	12.4	14	16.44	32.2	24.7	87	53.58	22.42	23.76
	Max	107.6	90	93	113	33	20.25	22	31.11	60.4	39.3	133.82	95.03	40.79	52.45
	SE(d) ±	2.29	1.98	2.06	2.63	0.48	0.37	0.45	0.58	1.11	0.83	2.07	1.82	0.56	0.83
	C.D. at 5%	4.59	3.98	4.14	5.27	0.97	0.75	0.91	1.16	2.22	1.67	4.15	3.66	1.13	1.66
	C.V. (%)	3.04	3.04	3.04	3.04	2.33	3.06	3.02	3.09	3.07	3.05	2.39	3.06	2.27	3.14

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