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Research Article

Estimation of genetic variability, heat susceptibility index and tolerance efficiency of wheat (*Triticum aestivum* L.) for timely and late sown environments

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Abstract
The present investigation was conducted to determine the genetic variability, Heat Susceptibility Index (HSI) and Heat Tolerance Efficiency (HTE) in 17 wheat genotypes including the checks over timely and late sown condition of *rabi* 2016-17 and 2017-18. On the basis of HSI for yield per plant, K1006, CG1507, PBW343 and HUW234 while UP2847, RWP 2015-22 and CG 1507 were observed to be tolerant in in 2016-17 and 2017-18, respectively. HSI for 1000 grain weight was observed to be tolerant in genotypes K 1006, RWP 2015-22, CG 1505, Lok-1 and NW 1014 in 2016-17and in genotypes K 1006, HD 2967 and DBW 14 in 2017-18, respectively. For HTE, CG 1507 (92.8%) and NW 1014 (113%) were best in 2016-17 and 2017-18, respectively. The genetic parameters showed significant variability among the genotypes and high broad sense heritability was observed for plant height in 2016-17 and for yield per plant and plant height in 2017-18.

Key words
Heat Susceptibility Index, Heat Tolerance Efficiency, genetic parameters, *Triticum aestivum*

INTRODUCTION

Among cereals, wheat is the second most important crop next to rice in production (FAOSTAT; 2019).It is a staple food crop for two-third of the India's population. Although the yield of wheat has increased substantially from 1950s to 2018 *i.e*, from 6.5mt to 101.2mt in year 2018-19(3rd AE, IIWBR 2019) from an area of 29.55 mha and the productivity of 34.24 q/ha. However, increasing population, shrinking cultivated land and the threat of environmental stresses remains the major challenges for increase in the productivity and production of wheat in India.

Among many abiotic and biotic stresses, terminal heat stress is one of the major constraint to the global wheat production, particularly in tropical and sub tropical regions of South Asia including large portion of India (Joshi *et al.,* 2007).Yield loss may be up to 40 % under severe heat stress (Hays *et al.*, 2007).Every 1^{0}C rise in temperature above 28^{0}C during GFD, results yield reduced by 3-4 % (Reynolds *et al.*, 1994). In many parts of the Asian subcontinent, rice-wheat cropping system is prevalent and due to late harvesting of rice crops, planting of wheat is delayed. Due to late sowing of wheat crop, cropping season is being pushed further and the grain filling period coincide with the rise in temperature, hence leading to terminal heat stress which significantly limits the yield of the crops (Aslam*et al.*, 1989). It has been observed that a heat wave (35–37^0 C) of 3–4 days modifies grain morphology and reduces grain size (Wardlaw and Wrigley, 1994). Hence, keeping in view the above facts and figures it is the need of the hour that we identify heat tolerant wheat genotypes which can be utilized in crop improvement programme to develop heat tolerant varieties in the future. In the present investigation heat susceptibility index and heat tolerance efficiency is used as a base to estimate the heat tolerance level of the 17 wheat genotypes.

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MATERIALS AND METHODS

The experiment was conducted in Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, which is located at 25.28^0N latitude and 82.95^0E longitude in north Gangetic plain of India. Seventeen wheat genotypes *viz*.,, HD2733, K1006, K0307, DBW 39, PHS 1106, UP2847, UP 2871, RWP-2015-22, CG1505, CG 1507, PBW343, Lok-1, HUW234, HUW510, NW1014, HD2967 (C_1), and DBW 14 (C_2) were sown in Randomized Block Design with two replications under timely and late sown conditions in *rabi* 2016-17 2017-18. The check HD 2967 was used for yield analysis while the check DBW 14 (heat tolerant) was used for heat tolerance analysis. Observations were recorded for 10 traits *viz*. days to 50% flowering (DF), days to 75% maturity (DM), grain filling duration (GFD), spike per plant (SPP), plant height (PH in cm), spike length (SL in cm), awn length (AL in cm), seeds per spike (SPS), yield per plant (YPP in gm) and 1000 grain weight (GW in gm). Observations were recorded on ten plants selected randomly and tagged before ear emergence. Each genotype was sown in two rows of 2m length and row-row spacing was 22.5 cm. Recommended agronomic practices were followed to raise a good and healthy crop. The heat sensitivity index (HSI) calculated according to Fisher and Maurer (1978) as given below,

$$\mathbf{X} = [(1-X_{stress}/X_{control})/D$$

Where, X = Trait of interest ,
X_{stress} = X in heat stress environment

$X_{control}$ = X in control environment,
D (stress Intensity) = (1 – $X^{stress}/X^{control}$)

X^{stress}= Mean of X^{stress} of all genotypes,
$X^{control}$= Mean of $X^{control}$ of all genotypes

(S ≤ 0.5 stress tolerant, S > 0.5 – 1.0 moderately stress tolerant and S > 1.0 susceptible).

Whereas, HTE was calculated according to Fischer and Wood (1981) as mentioned below,

HTE (%) = (Yield under stress /Yield under non-stress) × 100

(HTE value should be high for heat tolerant genotypes)

The genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) were calculated according to according to method given by Burton. While heritability (h^2) in broad sense and genetic advance (GA) as percentage of mean was calculated according to method given by Allard. For the estimation of the above parameters INDOSTAT software version9.2 was used.

RESULTS AND DISCUSSION

The genetic parameters for the 17 wheat genotypes in four environments timely and late sown in *rabi* 2016-17 and 2017-18) are presented in **Table 1**. It revealed the presence of sufficient variability under both timely and late sowing conditions among the genotypes studied in both the cropping seasons. The values of phenotypic coefficient of variation in both sowing conditions in both the years were slightly higher than that of genotypic coefficient of variation for all the traits taken under study, indicating less effect of environment on the expression of these characters. The high values of GCV were observed under timely sown condition 2016-17 (**Table 1**) for yield per plant (29.04) followed by spikes per plant (23.59) rest all the traits had lower values while, PCV was observed to be highest in yield per plant (29.98) followed by spikes per plant (24.41). The values of GCV was observed to be highest under late sown condition 2016-17 (**Table 1**) for spikes per plant (22.60) followed by yield per plant (17.55) while, PCV was observed to be highest in spikes per plant (23.46) followed by yield per plant (20.24). The values of GCV were observed to be high under timely sown condition 2017-18 (**Table 1**) for yield per plant (30.26) followed by spikes per plant (19.02) rest all the traits had lower values while, PCV was observed to be highest in yield per plant (30.70) followed by spikes per plant (22.60). The GCV values were observed highest under late sown condition 2017-18 (**Table 1**) for spikes per plant (25.51) followed by yield per plant (23.80) while, PCV values were observed to be highest in spikes per plant (27.67) followed by yield per plant (24.83). Narrow differences between phenotypic and genotypic coefficients of variation (PCV and GCV) for most of the characters revealed less environmental influence on their expression and hence, selection on the basis of phenotype will be reliable. Similar results were reported by Choudhary *et al*., 2015, Ramanuj *et al*., 2018 Raaj *et al*., 2018, Thakur *et al*., 2018 and Thapa *et al*., 2018. The above authors also reported the PCV value being more than the GCV values for all the traits studied by them in wheat genotypes.

The broad sense heritability was observed to be highest in plant height for both timely and late sown condition 2016-17 (**Table 1**) while the genetic advance at 5% was highest in plant height in both the conditions (**Table 1**). The per cent of mean at 5% was highest in yield per plant in timely sown condition while in late sown spikes per plant showed highest values. The broad sense heritability was observed to be highest in yield per plant for timely sown while for late sown condition plant height and days to 50% flowering had highest values in 2017-18 cropping season (**Table 1**) while the genetic advance at 5% was highest in plant height in both the conditions (**Table 1)**. The per cent of mean at 5% was highest in yield per plant in timely sown condition while in late sown spikes per plant showed highest values. These may be attributed to the preponderance of additive gene action and possessed high selective value and thus, selection pressure could profitably be applied on these characters for their rationale improvement. The results obtained are in agreement with the results reported by Singh *et al*., 2013, Bhanu *et al.,* 2018 and Khairnar *et al.,* 2018.

Table 1. Genetic parameters of the 17 wheat genotypes over four environments

Timely sown 2016-17

	DF	DM	GFD	SPP	PH	SL	AL	SPS	YPP	1000 GW
GCV	5.55	2.96	12.54	23.59	12.62	4.28	10.86	14.29	29.04	7.34
PCV	5.74	3.11	13.25	24.41	12.72	5.32	11.69	14.66	29.98	7.88
h² (Broad Sense)	0.94	0.91	0.90	0.93	0.98	0.65	0.86	0.95	0.94	0.87
Genetic Advancement 5%	9.99	7.26	8.45	3.94	22.85	1.18	1.27	15.58	7.21	5.91
Gen.Adv as % of Mean 5%	11.06	5.81	24.44	46.94	25.77	7.10	20.79	28.70	57.94	14.07
General Mean	90.29	124.88	34.59	8.39	88.68	16.56	6.13	54.28	12.44	42.00
Late Sown 2016-17										
GCV	5.31	2.12	10.47	22.60	13.10	7.53	7.54	11.81	17.55	8.20
PCV	5.48	2.36	11.70	23.46	13.15	7.94	9.29	12.30	20.24	8.72
h² (Broad Sense)	0.94	0.80	0.80	0.93	0.99	0.90	0.66	0.92	0.75	0.88
Genetic Advancement 5%	7.78	4.02	5.69	3.18	22.50	2.17	0.72	11.69	2.59	6.12
Gen.Adv as % of Mean 5%	10.61	3.91	19.30	44.84	26.90	14.69	12.61	23.34	31.36	15.88
General Mean	73.29	102.77	29.47	7.09	83.64	14.79	5.72	50.08	8.27	38.52
Timely sown 2017-18										
GCV	5.05	1.36	10.89	19.02	14.36	5.22	13.52	14.71	30.26	8.70
PCV	5.32	1.69	11.58	22.60	14.69	6.13	15.59	15.59	30.70	9.36
h² (Broad Sense)	0.90	0.65	0.89	0.71	0.96	0.73	0.75	0.89	0.97	0.87
Genetic Advancement 5%	8.28	2.67	7.30	3.36	26.50	1.53	1.45	17.13	10.05	6.81
Gen.Adv as % of Mean 5%	9.87	2.25	21.11	32.97	28.90	9.16	24.14	28.58	61.45	16.67
General Mean	83.91	118.47	34.56	10.21	91.69	16.72	6.01	59.94	16.36	40.86
Late Sown 2017-18										
GCV	5.77	2.96	12.06	25.51	11.99	3.80	10.04	8.08	23.80	6.61
PCV	5.87	3.26	13.12	27.67	12.15	6.45	14.22	10.14	24.83	7.40
h² (Broad Sense)	0.97	0.82	0.85	0.85	0.97	0.35	0.50	0.64	0.92	0.80
Genetic Advancement 5%	8.15	5.61	7.24	4.47	21.29	0.68	0.81	6.16	4.64	4.59
Gen.Adv as % of Mean 5%	11.67	5.52	22.84	48.44	24.36	4.60	14.59	13.27	47.00	12.16
General Mean	69.82	101.53	31.71	9.22	87.39	14.74	5.56	46.41	9.88	37.78

Table 2. Heat susceptibility Index(HSI) of 17 wheat genotypes for *rabi* 2016-17

	DF	DM	GFD	SPP	PH	SL	AL	SPS	YPP	1000 GW
HD 2733	0.88	0.94	1.14	0.79	1.34	1.72	0.66	0.83	0.63	1.85
K 1006	1.15	0.96	0.30	1.72	0.37	2.12	3.21	1.38	0.38	0.10
K 0307	0.80	0.83	0.93	-0.94	0.97	2.00	-0.22	-0.97	0.87	1.02
DBW 39	1.29	0.89	-0.66	2.63	0.44	0.72	0.30	0.43	0.56	1.55
PHS 1106	0.86	1.00	1.38	1.03	1.81	0.70	-2.25	1.92	1.34	-0.37
UP 2847	1.21	0.89	0.55	-0.61	-1.02	1.70	-1.32	-3.56	0.77	0.78
UP 2871	1.27	1.12	0.66	0.00	0.52	0.35	2.69	1.10	0.92	0.80
RWP 2015 22	1.09	1.00	0.74	0.46	0.49	0.00	-0.18	0.00	0.90	0.42
CG 1505	0.25	1.25	1.22	1.01	0.90	1.32	-0.32	2.63	0.98	0.29
CG 1507	1.03	0.89	0.34	0.16	0.74	1.02	1.90	1.31	0.21	1.76
PBW 343	1.18	1.20	1.19	1.87	0.67	-0.72	1.52	0.30	0.28	1.16
Lok-1	1.37	0.91	-1.28	0.67	0.66	1.08	2.17	1.17	0.63	0.29
HUW 234	1.02	1.65	1.32	1.56	-0.09	2.17	1.23	0.85	0.22	0.78
HUW 510	1.17	1.06	0.69	0.92	2.86	0.22	3.80	0.35	1.88	1.81
NW 1014	0.45	0.91	2.17	0.71	0.70	0.80	0.94	0.34	0.97	0.11
HD 2967	0.60	0.70	1.09	0.58	0.58	0.62	-0.42	0.62	1.36	0.52
DBW 14	0.57	0.74	1.26	-0.40	0.72	0.84	1.18	1.29	1.09	0.74

The estimate of genetic advance along with heritability is more useful for selection. High heritability with high genetic advance indicates that most likely the heritability is due to additive gene effects and selection may be effective in early generation for the traits under study.

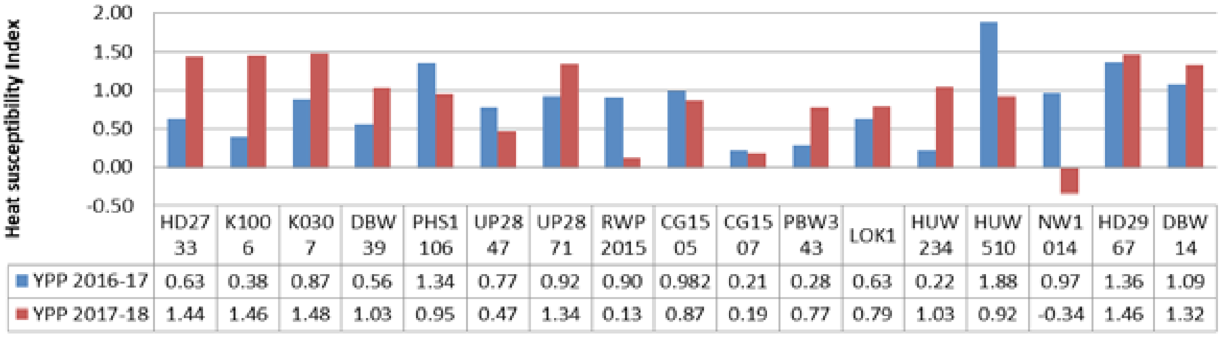

Fig.1. Heat susceptibility index of yield per plant (YPP) for 17 wheat genotypes in both cropping season in 2016-17 and 2017-18

Table 3. Heat susceptibility Index(HSI) of 17 wheat genotypes for rabi 2017-18

	DF	DM	GFD	SPP	PH	SL	AL	SPS	YPP	1000 GW
HD 2733	1.09	0.81	-1.32	1.87	1.52	0.57	-1.72	0.50	1.44	1.66
K 1006	0.81	1.18	3.03	1.60	0.33	1.15	2.59	0.80	1.46	0.09
K 0307	0.72	1.02	2.49	0.39	0.63	1.19	-1.70	0.98	1.48	1.77
DBW 39	0.83	0.99	1.81	3.67	1.97	0.44	1.32	1.37	1.03	1.98
PHS 1106	1.16	0.75	-0.73	3.22	0.11	1.02	1.48	1.32	0.95	-2.17
UP 2847	0.73	1.06	2.62	0.68	0.89	1.15	-3.31	0.98	0.47	1.81
UP 2871	1.02	0.97	0.82	0.61	0.24	0.26	2.79	0.98	1.34	0.78
RWP 2015 22	1.16	0.97	0.00	3.54	0.64	0.32	1.30	0.97	0.13	1.27
CG 1505	1.13	0.99	0.35	0.39	2.42	1.06	2.55	1.12	0.87	3.09
CG 1507	1.21	1.02	0.00	-2.52	2.94	0.74	1.64	1.05	0.19	0.88
PBW 343	0.99	0.79	-0.90	-2.41	0.71	0.66	2.18	1.33	0.77	1.70
Lok-1	1.05	1.09	1.35	0.71	-0.50	1.96	2.63	1.09	0.79	-0.04
HUW 234	0.95	1.07	1.66	2.50	0.82	1.95	-0.59	-0.20	1.03	1.74
HUW 510	1.06	1.07	1.18	-4.02	0.02	1.13	2.58	0.50	0.92	1.45
NW 1014	1.04	1.28	2.42	-1.93	1.58	0.40	-0.17	0.25	-0.34	-0.93
HD 2967	1.07	0.86	-0.62	3.32	0.27	1.44	-1.97	2.10	1.46	0.28
DBW 14	0.98	1.09	1.64	2.48	1.15	1.23	2.44	0.92	1.32	0.32

Heat susceptibility index (HSI) for *rabi* 2016-17 has been presented in **Table 2 and Fig 1**. For yield per plant 4 genotypes (K1006, CG 15057, PBW343 and HUW 234) showed tolerant HSI values *i.e*, <0.5 revealing that they were tolerant to heat when exposed to terminal heat stress condition these genotypes are while 9 genotypes *viz*., HD 2733, K 0307, DBW 39, UP 2847, UP 2871, RWP-2015 22, CG 1505, Lok-1 and NW 1014 showed moderate values of HSI *i.e*, 0.5-1.0 hence revealing they were moderately affected by heat stress,whereas 4 genotypes (PHS 1106, HUW 510, HD 2967 and DBW 14)were observed to be susceptible having values more than 1.0. Heat susceptibility index (HSI) for *rabi* 2017-18 has been presented in **Table 3 and Fig 2.** For yield per plant 3 genotypes (K 1006, HD 2967 and DBW 14) showed tolerant HSI values *i.e*, <0.5 revealing that they were tolerant these genotypes while 5 genotypes (PHS 1106, CG 1505, PBW 343, Lok-1 and HUW 510) showed moderate values of HSI *i.e*, 0.5-1.0 hence revealing they were moderately affected by heat stress and 8 genotypes (HD 2733, K 1006, K 0307, DBW 39, UP 2871, HUW 234, HD 2967 and DBW 14) were observed to be susceptible having values more than 1.0. Genotype NW 1014 showed negative value (-0.34) revealing that the yield per plant

Fig. 2. Heat susceptibility index of 1000 grain weight (1000 GW) for 17 wheat genotypes in both cropping season in 2016-17 and 2017-18

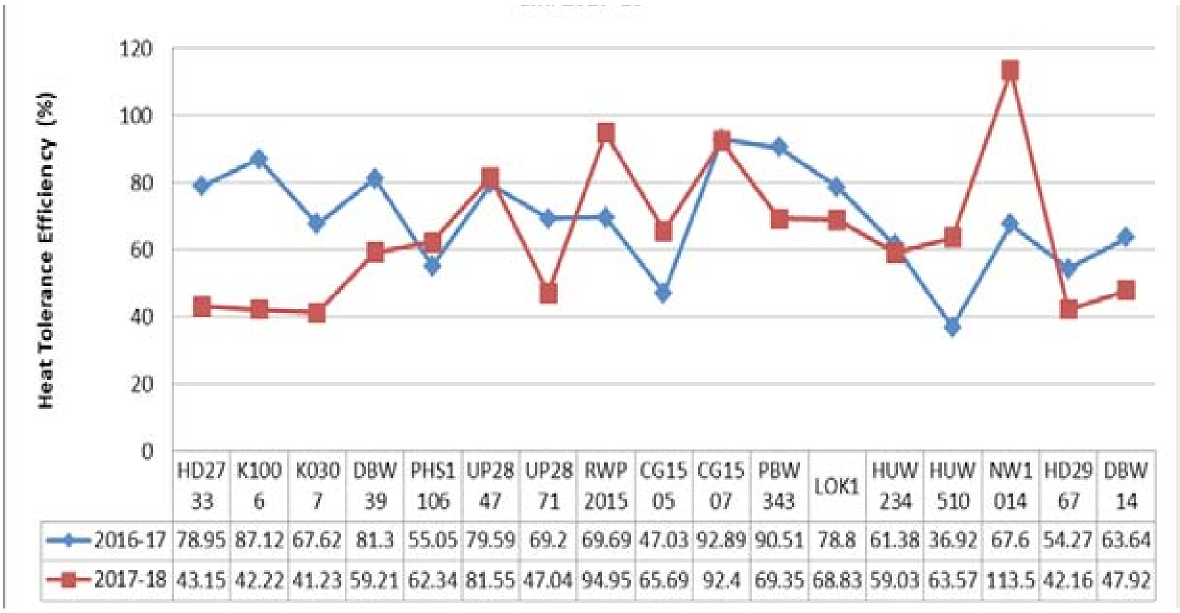

Fig.3. Heat tolerance efficiency for 17 wheat genotypes in both cropping season 2016-17 and 2017-18

was more in heat stress condition than the non- stress condition revealing that it is has more stable performance over different environments hence, is suitable for climate resilience. Heat susceptibility index (HSI) for rabi 2016-17 has been presented in Table 2 and Fig 1.For 1000 grain weight 5 genotypes viz.,, K1006, RWP 2015-22, CG 1505, Lok-1 and NW1014 showed tolerant HSI values i.e, <0.5 revealing that they were tolerant, while 5 genotypes (UP 2847, UP 2871, HUW 234, HD 2967 and DBW 14) showed moderate values of HSI i.e, 0.5-1.0 revealing they were moderately affected by heat stress and 6 genotypes (HD 2733, K 0307, DBW 39, CG 1507, PBW 343 and HUW 510) were observed to be susceptible having values more than 1.0. Genotype PHS 1106 showed negative value (-0.37) revealing that the 1000 Grain weight was more in heat stress condition than the non- stress condition revealing that it is has more stable performance over different environments hence, is suitable for climate resilience . Heat susceptibility index (HSI) for rabi 2017-18 has been presented in **Table 3 and Fig 2** for 1000 grain weight. Three genotypes *viz.,,* K 1006, HD 2967 and DBW 14 showed tolerant HSI values i.e, <0.5 revealing that they were tolerant, while 2 genotypes (UP 2871 and CG 1507) showed moderate values of HSI i.e, 0.5-1.0 revealing they were moderately affected by heat stress and 9 genotypes (HD 2733, K 0307, DBW 39, UP 2847, RWP 2015-22, CG 1505, PBW 343, HUW 234 and HUW 510) were observed to be susceptible having values more than 1.0. Genotype PHS 1106 (-2.17), Lok-1(-0.04) and NW 1014(-0.93) showed negative value revealing that the 1000 Grain weight was more in heat stress condition than the non- stress condition revealing that it is has more stable performance over different environments hence, is suitable for climate resilience also, photosynthesis and reproductive phase of plant growth are highly sensitive to high temperature stress therefore, a heat tolerant variety in this context should have a better photosynthetic rate, membrane thermo stability and fruit setting under high temperature (Nagarajan *et al.,* 2010) which is clearly expressed by the genotypes having negative values in the present study. The authors *viz*. Pandey *et al*., 2015, Bhardwaj *et al*., 2018 and suresh *et al*., 2018 have reported significant effects of the terminal heat stress in the yield per plant, 1000 grain weight and also in other yield related and physiological traits for terminal heat stress the wheat genotypes studied.

The Heat Tolerance Efficiency (HTE) for all the 17 genotypes for rabi 2016-17 and 2017-18 has been presented in graph **Fig 3.** For *rabi* 2016-17 the highest per cent tolerance level was shown by CG 1507 (92.8%) followed by PBW 343 (90.5%) while in rabi 2017-18 the highest values were shown by NW 1014 (113%) followed by RWP 2015-22 (94.9%) and CG 1507 (92.4%). Bahar and Yildirim (2010) reported similar result in bread wheat using same methodology for Drought Tolerance efficiency.

Plant height, yield per plant and spikes per plant for both the timely sown and late sown conditions in both the year *rabi* 2016-17 and *rabi* 2017-18 showed high heritability along with genetic advance and per cent of mean hence, selection on the basis of these traits in early generation be helpful for utilizing in breeding programme. Genotype CG 1507 showed low HSI values revealing high tolerance in both the cropping season for yield per plant while variety K1006 showed low HSI values showing high tolerance in both the cropping seasons for 1000 grain weight. CG 1507 showed high HTE values in both *rabi* seasons hence selection of these genotypes on the basis of HSI and HTE would help the breeder to develop tolerant varieties when involved in crop improvement programme.

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