The Pharma Innovation Journal 2022; 11(5): 1958-1962

www.ThePharmaJournal.com

The Pharma Innovation

**ISSN (E): 2277-7695**
**ISSN (P): 2349-8242**
**NAAS Rating: 5.23**
TPI 2022; 11(5): 1958-1962

www.thepharmajournal.com
Received: 07-02-2022
Accepted: 16-03-2022

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# Study of heat susceptibility index for grain yield and associated traits in bread wheat (*Triticum aestivum* L.)

**Madhu Choudhary, H Singh, D Gupta, Madhu Yadav, Sonu Get and Rajwanti Saran**

## Abstract
This experiment was conducted for estimated terminal heat stress in wheat cultivation that a severe threat resultant severe loss of yield. Due to heat stress, reduction in all the traits specially grain yield, thousands kernel weight and grain filling duration by 46.63, 20.61 and 20.42 per cent, respectively. High temperature adversely affects survivability of the tillers per plant, that causes decrease in grain yield of the wheat. Therefore, it is prerequisite to develop high-yielding and heat tolerant varieties. In the present study parents *viz.,* Raj 4037, DBW 90, PBW 502 and UP 2425 and crosses *viz.,* DPW 621-50 x Raj 4037, DPW 621-50 x Raj 4079 in $F_1$ and Raj 4037 x Raj 3765 and Raj 3765 x Raj 4079, DBW 90 x Raj 4037 and DPW 621-50 x Raj 4037 in $F_2$ were found the most desirable as they have high heat tolerant for most of the traits examined. The heat susceptibility index may be engaged as important criteria for breeding of wheat genotypes suitable for heat stress condition.

**Keywords:** Wheat, heat stress, traits, yield, heat susceptibility, etc.

## Introduction
Wheat is a major staple food crop of the world. It is one of the most important and widely cultivated crop in the world, mainly used for human consumption and support nearly 35 per cent of the world population. It is believed to be originated Near East Region of South-West Asia (Lupton,1987) [16]. The bread wheat (*Triticum aestivum* L.) is a mid-tall annual grass with flat leaf blades and a terminal floral spike consisting of perfect flowers. The vegetative part of the plant described by tillers carriage axillary leafy culms, comprises 5-7 nodes with 3-4 foliage leaves. The flag or uppermost leaf define the inflorescence (Lersten, 1987) [15].
In India, it is grown in about an area of 31.45 million ha with the production of 107.59 million tonnes and average productivity 3420 kg per hectare (Anonymous, 2020a) [2]. In Rajasthan, it occupies an area of 34.97 lakh ha with the production 13.88 million tonnes and average productivity 3971 kg per hectare (Anonymous, 2020b) [3]. Changing climate condition is the major factor that influences crop production. During the period from 1880 to 2012, the earth's system warmed by 0.85°C (IPCC, 2014) [12]. This warming period will continue and is predicted to rise between the range of 1.5-4.0°C in the future (Wheeler and Braun, 2013). Wheat is a thermo-sensitive crop mostly grown in temperate environment. In general optimum temperature required by wheat crop is 18 to 24 °C (Bahar *et al.*, 2011) [5] but during anthesis and grain filling cardinal temperature is 12 to 22 °C (Farooq *et al.*, 2011) [9]. Exposure to temperatures above 12 to 22 $^0$C significantly reduces grain yield and deteriorates the grain quality (Tewolde *et al.*, 2006) [21]. In subtropical region wheat is cultivated in winter season but it exposed to heat stress at the end of the season *i.e.* at grain filling stage. As per estimate, wheat yield reduces by 6 per cent at each degree rise in temperature (Akter and Islam, 2017) [1]. Heat stress shortens grain-filling duration or post anthesis period (Wiegand and Cuellar, 1981) [23].
Looking to these facts, there is a need to develop varieties that would give stable production under heat stress conditions. Breeding is an adaptation response of crops in the changing climatic conditions. It requires the evaluation of genetic diversity for adaptation to heat stress and selection and induction of stress inducible genes from genetic resources for developing heat tolerant varieties in the production systems (Chapman *et al.*, 2012) [7]. The recombination of different desirable traits spread over in different diverse genotypes is important to recombine for the improvement in yield and its related traits in wheat. Genetic information concerning yield and its contributing traits give significantly in the selection of desirable parents and generations to develop and carry out effective breeding programme to develop high yielding and stress tolerant varieties.

## Material and Methods

The present investigation was conducted to analyse combining ability heterosis, heterobeltiosis, inbreeding depression, components of genetic variance and heat stress tolerance for grain yield and its contributing traits in bread wheat (*Triticum aestivum* L. em. Thell.) in two varying environments created by two dates of sowing *viz.*, normal sown and late sown conditions at Agricultural Research Farm of Rajasthan Agricultural Research Institute, Durgapura, Sri Karan Narendra Agriculture University, Jobner, Jaipur (Rajasthan). The ten genetically diverse parents *viz.*, DPW 621-50, DBW 90, PBW 502, Raj 1482, Raj 4037, UP 2425, Raj 3765, PBW 550, HI 1563 and Raj 4079 crossed in half-diallel fashion (excluding reciprocals) in *rabi* 2018-19 and for the advance generation $F_1$'s seed was grown at Wellington (Tamil Nadu), IARI regional sub-station in *kharif* 2019. The ten parents along with their 45 $F_1$'s and 45 $F_2$'s were evaluated in a randomized block design with three replications each in two environments during *rabi* 2019-20. The observations were recorded for days to heading, days to maturity, plant height, tillers per plant, flag leaf area, spike length, grains per ear, 1000-grain weight, biomass per plant, grain yield per plant, harvest index, canopy temperature and protein content.

Heat susceptibility index (HSI) was calculated for grain yield and other attributes over high temperature or heat stress (late sown) and non-stress environment (normal sown) by using the formula suggested by Fischer and Maurer (1978).

$$\text{HSI} = \left[1 - \frac{YD}{YP}\right] / D$$

**Where**

YD = mean of the genotype in stress environment.

YP = mean of the genotype under non-stress environment.

D = 1- [mean of all genotype in stress environment/mean of all genotype in non-stress environment]

The HSI values were used to characterize the relative tolerance of genotype based on minimization of yield losses compared to normal environmental condition.

## Result and Discussion

The mean performance of parents, $F_1$'s and $F_2$'s under late sown environment ($E_2$) in comparison to normal sown ($E_1$). The heat susceptibility index (HSI) was calculated individually for each character in stress environment *i.e.* late sown ($E_2$) against normal sown ($E_1$). Similar result with Shpiler and Blum (1990) [20], Dhanda and Munjal (2006) [8] and Prakash (2007) [18]. On the basis of HSI, the parents, $F_1$'s and $F_2$'s were classified as highly tolerant, tolerant, moderately tolerant and susceptible to heat stress (Table1).

As obvious, least affected parents for different traits under late sown condition ($E_2$) were HI 1563, Raj 3765, and Raj 4037 for days to heading; PBW 550, Raj 4079 and PBW 502 for days to maturity; DBW 90, Raj 1482 and PBW 502 for plant height Raj 3765, Raj 4079 and UP 2425 for biomass per plant; UP 2425, PBW 502 and Raj 4037 for harvest index; UP 2425, Raj 4037 and Raj 4079 for grain yield per plant; PBW 550, Raj 4037 and DBW 90 for canopy temperature. An overall evaluation of parents for all the studied characters revealed that UP 2425, PBW 502, Raj 4037 and Raj 4079 were found desirable for most of the characters on the basis of HSI. Khatib and Paulsen (1999) [13], Ibrahim and Quick (2001) [11] and Bhardwaj *et al.* (2017) [6] observed similar results for these characters in wheat.

Heat susceptibility index (HSI) in $F_1$'s, showed that the crosses *viz.* UP 2425 x Raj 3765, Raj 1482 x HI 1563, UP 2425 x Raj 4079, Raj 3765 x HI 1563 and Raj 1482 x UP 2425 for days to heading; Raj 3765 x PBW 550, Raj 3765 x Raj 4079, DPW 621-50 x UP 2425, DPW 621-50 x Raj 1482 and Raj 1482 x Raj 4079 for days to maturity; UP 2425 x HI 1563, Raj 4037 x UP 2425, Raj 3765 x PBW 550, DBW 90 x Raj 3765 and PBW 550 x Raj 4079 for plant height DBW 90 x Raj 4037, DPW 621-50 x Raj 4037, DBW 90 x UP 2425, DPW 621-50 x PBW 550 and Raj 4037 x Raj 3765 for grain yield per plant; DPW 621-50 x Raj 3765, Raj 4037 x Raj 3765, DPW 621-50 x Raj 4079, Raj 4037 x Raj 4079 and UP 2425 x PBW 550 for canopy temperature; An overall evaluation of $F_1$ crosses for all the studied characters revealed that *viz.*, DPW 621-50 x Raj 4037, DPW 621-50 x Raj 4079, Raj 4037 x Raj 3765, DPW 621-50 x PBW 550, DBW 90 x Raj 4037, DBW 90 x UP 2425, Raj 3765 x HI 1563, and Raj 3765 x Raj 4079 were found proficient for most of characters on the basis of HSI. The results of this research were in accordance with earlier reports of Kumar *et al.* (2017) and Aziz *et al.* (2018).

Perusal of Table 1 in $F_2$'s, showed that the crosses *viz.*, UP 2425 x Raj 3765, PBW 502 x HI 1563, Raj 3765 x HI 1563, PBW 502 x UP 2425 and Raj 1482 x HI 1563 for days to heading; Raj 3765 x Raj 4079, Raj 4037 x Raj 4079, Raj 4037 x Raj 3765, DBW 90 x Raj 4079 and DPW 621-50 x UP 2425 for days to maturity; DBW 90 x Raj 4037, Raj 3765 x Raj 4079, PBW 502 x UP 2425, DPW 621-50 x DBW 90 and DPW 621-50 x Raj 4037 for grain yield per plant; An entire evaluation of $F_2$ crosses for all the studied characters revealed that the crosses Raj 3765 x Raj 4079, DBW 90 x Raj 4079, DPW 621-50 x Raj 4037, DPW 621-50 x DBW 90, PBW 502 x UP 2425, PBW 502 x HI 1563 and Raj 4037 x Raj 4079 were detected to be desirable for most of characters on the basis of HSI. The result of experiment for different characters were conformity with the finding of several researchers such as Narayanan (2018) [17] and Sareen *et al.* (2018) [19].

Similarly, across the generations indicated the superiority of the crosses *viz.*, The crosses DPW 621-50 x Raj 4037 and DBW 90 x Raj 4037 under late sown condition ($E_2$). The low heat stress intensity (D-value) revealed that the parameters were *viz.* flag leaf area (0.12), spike length (0.14), tillers per plant (0.10), canopy temperature (0.17), protein content (0.19) and biomass per plant (0.11) were less affected whereas, grains per ear (0.25), 1000-grain weight (0.32), harvest index (0.37), grain yield (0.29), plant height (0.34) days to heading (0.25) and days to maturity (0.36) with high heat stress intensity (D-value) suffered more under late sown environment ($E_2$). Bhardwaj *et al.* (2017) [6] and Prakash (2007) [18] was reported high D-value for grain yield per plant.

**Table 1:** Heat susceptibility indices for yield and its contributing traits under late sown ($E_2$) condition in comparison to normal ($E_1$) sown condition

| Parents/Crosses | Days to heading | Days to maturity | Plant height | Tillers per plant | Flag leaf area | Spike length | Grains per ear | 1000-grain weight | Biomass per plant | Grain yield per plant | Harvest Index | Canopy temperature | Protein content |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DPW 621-50 | 1.06 | 1.05 | 1.03 | 1.23 | 1.33 | 0.80 | 0.82 | 0.98 | 0.13 | 1.77 | 2.25 | 1.26 | 0.40 |
| DBW 90 | 1.13 | 1.05 | 0.76 | 1.08 | 1.21 | 0.77 | 0.63 | 0.87 | 2.11 | 1.34 | 1.00 | 0.82 | 0.85 |
| PBW 502 | 1.12 | 0.97 | 0.94 | 1.12 | 0.41 | 1.33 | 1.26 | 0.98 | 1.57 | 0.70 | 0.38 | 1.24 | 0.74 |
| Raj 1482 | 1.06 | 0.98 | 0.76 | 1.11 | 0.85 | 0.57 | 1.50 | 1.00 | 2.50 | 1.42 | 1.06 | 0.87 | 1.46 |
| Raj 4037 | 0.89 | 1.00 | 0.95 | 0.81 | 0.77 | 0.43 | 1.12 | 1.13 | 0.36 | 0.65 | 0.72 | 0.79 | 0.86 |
| UP 2425 | 0.94 | 1.07 | 1.21 | 0.71 | 0.85 | 1.17 | 0.96 | 1.16 | 0.32 | 0.36 | 0.36 | 0.99 | 1.19 |
| Raj 3765 | 0.83 | 1.11 | 1.13 | 0.95 | 1.03 | 0.92 | 1.02 | 0.74 | 0.21 | 0.76 | 0.92 | 1.11 | 0.68 |
| PBW 550 | 1.19 | 0.80 | 0.98 | 1.04 | 1.22 | 0.96 | 0.58 | 1.41 | 0.65 | 1.04 | 1.15 | 0.64 | 1.24 |
| HI 1563 | 0.80 | 1.02 | 1.10 | 1.14 | 1.13 | 1.60 | 0.81 | 0.51 | 1.74 | 1.66 | 1.66 | 1.17 | 1.31 |
| Raj 4079 | 0.93 | 0.94 | 1.15 | 0.81 | 1.14 | 1.25 | 1.23 | 1.17 | 0.31 | 0.66 | 0.75 | 1.07 | 1.17 |
| **$F_1$ crosses** | | | | | | | | | | | | | |
| DPW 621-50 x DBW 90 | 0.81 | 1.15 | 0.94 | 0.86 | 0.64 | 0.81 | 0.32 | 0.98 | 1.89 | 2.05 | 2.20 | 1.07 | 1.37 |
| DPW 621-50 x PBW 502 | 1.15 | 1.05 | 0.98 | 0.98 | 0.72 | 1.60 | 1.22 | 0.80 | 1.90 | 1.17 | 0.78 | 1.11 | 0.54 |
| DPW621-50 x RAJ 1482 | 1.35 | 0.68 | 1.00 | 1.12 | 1.79 | 1.14 | 0.99 | 1.70 | 1.00 | 1.04 | 1.05 | 0.74 | 0.79 |
| DPW6 21-50 x Raj 4037 | 0.94 | 0.90 | 0.74 | 0.93 | 0.53 | 0.92 | 1.10 | 1.00 | 0.07 | 0.17 | 0.23 | 0.68 | 0.33 |
| DPW 621-50 x UP 2425 | 0.91 | 0.65 | 1.01 | 1.02 | 1.04 | 0.17 | 1.32 | 0.90 | 1.77 | 1.14 | 0.77 | 1.27 | 0.49 |
| DPW 621-50 x Raj 3765 | 0.97 | 0.84 | 1.17 | 0.98 | 0.94 | 0.72 | 0.99 | 0.05 | 1.68 | 0.85 | 0.36 | 0.01 | 1.55 |
| DPW 621-50 x PBW 550 | 1.56 | 0.89 | 1.46 | 1.20 | 1.68 | 1.52 | 1.12 | 0.79 | 0.03 | 0.27 | 0.38 | 0.61 | 0.43 |
| DPW 621-50 x HI 1563 | 0.81 | 1.18 | 1.02 | 1.30 | 1.34 | 1.98 | 2.37 | 0.66 | 1.24 | 1.11 | 1.03 | 0.66 | 1.63 |
| DPW 621-50 x Raj 4079 | 1.02 | 0.94 | 0.90 | 0.81 | 1.02 | 0.23 | 1.00 | 0.59 | 0.91 | 0.78 | 0.68 | 0.44 | 0.88 |
| DBW 90 x PBW 502 | 1.39 | 1.18 | 0.98 | 1.07 | 1.01 | 0.78 | 0.93 | 1.15 | 1.32 | 0.80 | 0.48 | 1.25 | 1.75 |
| DBW 90 x Raj 1482 | 0.93 | 0.85 | 1.07 | 0.96 | 1.16 | -0.18 | 0.72 | 0.90 | 0.15 | 1.04 | 1.45 | 0.99 | 1.20 |
| DBW 90 x Raj 4037 | 1.02 | 0.98 | 1.03 | 1.33 | 0.78 | 0.80 | 1.15 | 0.95 | 0.06 | 0.11 | 0.11 | 0.93 | 1.19 |
| DBW 90 x UP 2425 | 0.94 | 1.36 | 1.13 | 1.19 | 1.23 | 0.74 | 0.15 | 1.91 | 0.35 | 0.24 | 0.18 | 1.07 | 1.85 |
| DBW 90 x Raj 3765 | 0.95 | 0.76 | 0.57 | 0.98 | 0.70 | 0.95 | 0.85 | 0.81 | 0.65 | 0.58 | 0.52 | 0.83 | 0.78 |
| DBW 90 x PBW 550 | 1.27 | 1.05 | 1.05 | 1.11 | 1.72 | 0.59 | 1.71 | 0.79 | 0.63 | 1.11 | 1.33 | 0.90 | 0.67 |
| DBW 90 x HI 1563 | 1.11 | 0.95 | 1.36 | 0.79 | 0.69 | 1.30 | 1.11 | 0.70 | 0.81 | 1.66 | 2.08 | 1.02 | 1.36 |
| DBW 90 x Raj 4079 | 1.03 | 0.80 | 0.96 | 0.82 | 0.70 | 0.61 | 1.01 | 0.06 | 0.55 | 0.72 | 0.74 | 1.11 | 0.60 |
| PBW 502 x Raj 1482 | 1.24 | 0.90 | 0.98 | 0.82 | 0.90 | 0.68 | 2.25 | 1.14 | 0.32 | 2.47 | 3.46 | 1.08 | 2.00 |
| PBW 502 x Raj 4037 | 1.26 | 1.15 | 0.92 | 0.89 | 0.80 | 0.73 | 1.12 | 0.87 | 0.87 | 0.78 | 0.72 | 1.27 | 1.07 |
| PBW 502 x UP 2425 | 0.84 | 1.16 | 1.37 | 1.00 | 0.92 | 1.16 | 1.51 | 0.75 | 1.05 | 0.97 | 0.89 | 1.25 | 1.74 |
| PBW 502 x Raj 3765 | 1.30 | 0.87 | 1.03 | 0.91 | 2.18 | 0.49 | 1.13 | 1.42 | 0.79 | 0.61 | 0.48 | 0.87 | 0.80 |
| PBW 502 x PBW 550 | 0.96 | 1.18 | 0.91 | 1.04 | 1.49 | 0.78 | 1.32 | 0.55 | 1.76 | 0.98 | 0.55 | 0.84 | 0.64 |
| PBW 502 x HI 1563 | 0.95 | 1.14 | 1.01 | 0.94 | 0.60 | 1.06 | 0.38 | 0.84 | 0.66 | 1.26 | 1.54 | 1.36 | 1.29 |
| PBW 502 x Raj 4079 | 1.26 | 0.84 | 1.03 | 0.79 | 0.73 | 0.79 | 0.95 | 0.63 | 0.46 | 0.77 | 0.89 | 1.97 | 0.64 |
| Raj 1482 x Raj 4037 | 1.34 | 1.04 | 1.41 | 1.07 | 0.96 | 1.11 | 1.28 | 1.76 | 1.61 | 1.35 | 1.14 | 1.05 | 0.96 |
| Raj 1482 x UP 2425 | 0.54 | 0.93 | 0.94 | 1.17 | 0.60 | 1.21 | 1.06 | 1.39 | 0.66 | 0.82 | 0.82 | 0.93 | 0.74 |
| Raj 1482 x Raj 3765 | 1.01 | 1.26 | 1.16 | 0.91 | 1.30 | 1.19 | 0.84 | 1.15 | 0.44 | 0.73 | 0.86 | 1.03 | 0.96 |
| Raj 1482 x PBW 550 | 1.02 | 1.13 | 0.98 | 1.24 | 1.24 | 1.31 | 0.07 | 0.89 | 1.76 | 0.98 | 0.65 | 1.00 | 1.17 |
| Raj 1482 x HI 1563 | 0.37 | 0.77 | 1.00 | 1.07 | 0.74 | 1.36 | 0.49 | 1.00 | 0.52 | 1.17 | 1.48 | 0.92 | 0.92 |
| Raj 1482 x Raj 4079 | 1.31 | 0.74 | 1.03 | 0.94 | 0.96 | 1.12 | 1.86 | 1.08 | 1.88 | 0.99 | 0.48 | 0.92 | 0.36 |
| Raj 4037 x UP 2425 | 0.78 | 1.24 | 0.47 | 0.93 | 1.18 | 1.63 | 1.02 | 0.86 | 0.64 | 1.34 | 1.65 | 1.08 | 0.45 |
| Raj 4037 x Raj 3765 | 1.21 | 0.80 | 0.99 | 0.83 | 0.89 | 0.41 | 0.84 | 0.73 | 0.33 | 0.27 | 0.22 | 0.38 | 0.62 |
| Raj 4037 x PBW 550 | 1.16 | 1.11 | 1.48 | 1.18 | 1.03 | 0.91 | 0.95 | 1.09 | 0.93 | 1.24 | 1.41 | 1.18 | 0.84 |
| Raj 4037 x HI 1563 | 1.17 | 1.03 | 0.97 | 1.12 | 0.81 | 1.40 | 1.05 | 1.27 | 0.81 | 1.23 | 1.43 | 1.09 | 0.76 |
| Raj 4037 x Raj 4079 | 1.36 | 0.84 | 1.43 | 1.01 | 0.79 | 0.50 | 0.87 | 0.73 | 0.47 | 0.37 | 0.29 | 0.54 | 0.57 |
| UP 2425 x Raj 3765 | 0.16 | 1.23 | 1.40 | 0.89 | 0.76 | 0.83 | 0.74 | 1.19 | 1.84 | 2.08 | 2.33 | 1.14 | 0.87 |
| UP 2425 x PBW 550 | 0.73 | 0.97 | 0.97 | 1.04 | 0.39 | 1.23 | 0.98 | 2.09 | 1.32 | 1.14 | 1.04 | 0.58 | 1.01 |
| UP 2425 x HI 1563 | 0.63 | 1.56 | 0.44 | 1.01 | 1.22 | 1.63 | 1.14 | 0.76 | 2.09 | 2.01 | 2.09 | 1.11 | 1.29 |
| UP 2425 x Raj 4079 | 0.49 | 1.21 | 0.69 | 1.08 | 0.25 | 1.47 | 0.38 | 0.66 | 1.68 | 1.22 | 0.96 | 0.84 | 1.73 |
| Raj 3765 x PBW 550 | 0.84 | 0.27 | 0.56 | 1.11 | 0.65 | 1.30 | 1.51 | 1.01 | 0.85 | 1.35 | 1.65 | 1.23 | 1.61 |
| Raj 3765 x HI 1563 | 0.53 | 1.26 | 0.87 | 0.81 | 0.89 | 0.92 | 0.10 | 1.31 | 0.86 | 0.99 | 1.03 | 0.95 | 0.91 |
| Raj 3765 x Raj 4079 | 1.25 | 0.56 | 0.70 | 0.76 | 0.94 | 0.75 | 1.04 | 0.65 | 0.50 | 0.59 | 0.62 | 0.80 | 0.32 |
| PBW 550 x HI 1563 | 1.07 | 1.16 | 0.80 | 1.35 | 1.50 | 1.54 | 0.99 | 1.63 | 1.19 | 0.83 | 0.61 | 1.48 | 0.94 |
| PBW 550 x Raj 4079 | 1.06 | 1.11 | 0.68 | 0.86 | 0.71 | 1.33 | 0.17 | 1.67 | 2.53 | 2.40 | 2.54 | 1.27 | 0.74 |
| HI 1563 x Raj 4079 | 0.97 | 1.16 | 1.02 | 0.99 | 1.34 | 1.41 | 0.30 | 1.34 | 0.68 | 0.55 | 0.41 | 1.37 | 1.31 |
| **$F_2$ crosses** | | | | | | | | | | | | | |
| DPW 621-50 x DBW 90 | 0.95 | 1.08 | 1.09 | 0.95 | 0.54 | 1.04 | 1.26 | 0.31 | 0.20 | 0.19 | 0.27 | 1.06 | 1.16 |
| DPW 621-50 x PBW 502 | 1.12 | 1.16 | 1.05 | 0.70 | 0.58 | 0.40 | 1.50 | 1.09 | 1.36 | 1.22 | 1.14 | 1.21 | 0.52 |
| DPW621-50 x RAJ 1482 | 1.46 | 0.73 | 1.06 | 1.05 | 1.57 | 0.78 | 1.12 | 1.49 | 0.93 | 0.81 | 0.65 | 0.82 | 0.85 |
| DPW6 21-50 x Raj 4037 | 0.87 | 0.83 | 0.72 | 0.94 | 1.26 | 1.18 | 1.10 | 1.02 | 0.25 | 0.22 | 0.17 | 0.56 | 0.28 |
| DPW 621-50 x UP 2425 | 0.96 | 0.64 | 0.76 | 0.92 | 1.13 | 0.25 | 1.58 | 0.78 | 0.44 | 1.67 | 2.87 | 1.30 | 0.50 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DPW 621-50 x Raj 3765 | 0.83 | 0.72 | 1.19 | 0.86 | 1.14 | 0.69 | 0.55 | -0.06 | 0.36 | 0.50 | 0.60 | 0.47 | 1.17 |
| DPW 621-50 x PBW 550 | 1.54 | 1.01 | 1.48 | 1.09 | 1.75 | 1.39 | 1.44 | 0.69 | 0.02 | 0.55 | 1.12 | 0.85 | 0.80 |
| DPW 621-50 x HI 1563 | 0.65 | 1.07 | 0.87 | 1.42 | 0.60 | 1.47 | 1.22 | 0.54 | 1.60 | 1.29 | 0.99 | 1.22 | 1.77 |
| DPW 621-50 x Raj 4079 | 0.95 | 0.98 | 0.85 | 0.82 | 1.10 | 0.54 | 1.07 | 0.61 | 1.01 | 0.91 | 0.76 | 0.30 | 0.41 |
| DBW 90 x PBW 502 | 1.27 | 1.12 | 0.80 | 1.23 | 0.92 | 1.04 | 1.10 | 1.24 | 0.90 | 1.04 | 1.13 | 1.42 | 1.31 |
| DBW 90 x Raj 1482 | 1.06 | 0.83 | 1.13 | 0.96 | 0.56 | 1.03 | 1.17 | 0.76 | 1.85 | 1.08 | 0.12 | 0.90 | 0.74 |
| DBW 90 x Raj 4037 | 1.08 | 0.74 | 1.34 | 0.94 | 1.07 | 0.47 | 1.25 | 0.80 | 0.04 | 0.07 | 0.09 | 1.08 | 1.12 |
| DBW 90 x UP 2425 | 0.75 | 1.39 | 1.15 | 1.15 | 0.81 | 0.96 | 0.40 | 2.10 | 1.23 | 1.44 | 1.66 | 1.17 | 2.18 |
| DBW 90 x Raj 3765 | 0.93 | 0.95 | 0.63 | 0.84 | 1.15 | 0.94 | 0.52 | 1.26 | 0.17 | 0.29 | 0.39 | 0.79 | 1.16 |
| DBW 90 x PBW 550 | 1.37 | 1.05 | 1.14 | 1.03 | 1.38 | 1.31 | 0.12 | 0.90 | 0.58 | 1.01 | 1.41 | 1.04 | 0.98 |
| DBW 90 x HI 1563 | 1.24 | 0.97 | 1.11 | 1.01 | 0.95 | 1.30 | 0.05 | 0.25 | 0.65 | 1.31 | 1.95 | 1.00 | 1.36 |
| DBW 90 x Raj 4079 | 1.18 | 0.63 | 0.59 | 0.50 | 1.15 | 0.76 | 0.11 | 0.55 | 0.93 | 0.75 | 0.52 | 0.60 | 0.20 |
| PBW 502 x Raj 1482 | 1.20 | 0.85 | 0.99 | 0.95 | 0.53 | 0.14 | 0.99 | 1.03 | 0.55 | 1.20 | 1.78 | 1.03 | 1.59 |
| PBW 502 x Raj 4037 | 1.13 | 1.08 | 0.88 | 1.13 | 1.17 | 0.21 | 0.87 | 1.13 | 2.98 | 1.80 | 0.50 | 1.38 | 1.26 |
| PBW 502 x UP 2425 | 0.58 | 1.28 | 1.12 | 1.05 | 0.76 | 1.19 | 0.81 | 0.40 | 0.01 | 0.16 | 0.31 | 1.13 | 1.51 |
| PBW 502 x Raj 3765 | 1.25 | 0.71 | 1.59 | 1.08 | 2.07 | 0.51 | 1.34 | 1.30 | 0.17 | 0.94 | 1.66 | 1.09 | 1.08 |
| PBW 502 x PBW 550 | 1.12 | 1.08 | 0.90 | 1.08 | 0.95 | 1.36 | 0.27 | 0.04 | 1.42 | 1.22 | 0.99 | 0.76 | 0.02 |
| PBW 502 x HI 1563 | 0.41 | 1.43 | 1.11 | 0.94 | 0.34 | 1.67 | 0.17 | 1.60 | 2.17 | 1.89 | 1.75 | 1.03 | 0.77 |
| PBW 502 x Raj 4079 | 1.31 | 0.87 | 1.06 | 0.86 | 1.01 | 0.18 | 0.16 | 1.71 | 1.38 | 0.99 | 0.52 | 1.36 | 0.50 |
| Raj 1482 x Raj 4037 | 1.32 | 1.16 | 1.31 | 1.09 | 1.33 | 0.93 | 1.88 | 1.40 | 2.16 | 1.76 | 1.43 | 0.85 | 1.14 |
| Raj 1482 x UP 2425 | 0.77 | 0.67 | 1.04 | 1.14 | 0.46 | 1.84 | 1.39 | 1.62 | 0.15 | 1.00 | 1.79 | 1.05 | 0.96 |
| Raj 1482 x Raj 3765 | 1.22 | 1.38 | 0.92 | 0.92 | 1.49 | 1.17 | 1.08 | 1.04 | 0.78 | 0.76 | 0.69 | 0.83 | 1.58 |
| Raj 1482 x PBW 550 | 0.90 | 1.08 | 1.23 | 1.20 | 1.33 | 0.86 | 0.29 | 0.83 | 1.73 | 1.32 | 0.86 | 1.14 | 0.55 |
| Raj 1482 x HI 1563 | 0.60 | 1.29 | 0.89 | 0.90 | 0.59 | 1.20 | 0.64 | 0.81 | 1.56 | 1.16 | 0.69 | 0.58 | 1.58 |
| Raj 1482 x Raj 4079 | 1.01 | 0.84 | 1.34 | 1.00 | 0.46 | 0.87 | 1.57 | 0.38 | 0.78 | 0.59 | 0.35 | 0.86 | 0.72 |
| Raj 4037 x UP 2425 | 0.90 | 1.14 | 0.56 | 1.00 | 1.09 | 1.41 | 0.79 | 0.75 | 0.58 | 1.19 | 1.71 | 0.80 | 0.01 |
| Raj 4037 x Raj 3765 | 1.22 | 0.62 | 0.75 | 0.84 | 0.95 | 0.59 | 0.76 | 0.57 | 0.11 | 0.29 | 0.44 | 0.99 | 0.34 |
| Raj 4037 x PBW 550 | 1.05 | 1.04 | 1.54 | 1.15 | 1.15 | 0.79 | 1.39 | 0.90 | 1.03 | 1.35 | 1.61 | 1.03 | 0.55 |
| Raj 4037 x HI 1563 | 1.21 | 1.07 | 0.73 | 1.08 | 0.37 | 1.58 | 1.24 | 0.14 | 1.43 | 1.29 | 1.14 | 1.33 | 1.19 |
| Raj 4037 x Raj 4079 | 1.29 | 0.40 | 1.28 | 0.76 | 1.35 | 0.50 | 0.91 | 1.17 | 0.36 | 0.40 | 0.40 | 1.07 | 0.09 |
| UP 2425 x Raj 3765 | 0.31 | 1.14 | 1.08 | 1.10 | 0.54 | 0.58 | 1.27 | 1.10 | 1.49 | 1.00 | 0.42 | 1.03 | 1.29 |
| UP 2425 x PBW 550 | 0.77 | 0.87 | 1.09 | 0.99 | 0.20 | 1.31 | 0.94 | 1.82 | 0.92 | 0.93 | 0.93 | 0.95 | 1.13 |
| UP 2425 x HI 1563 | 0.68 | 1.52 | 0.83 | 1.06 | 1.10 | 1.40 | 0.95 | 1.16 | 1.60 | 1.91 | 2.53 | 0.96 | 2.17 |
| UP 2425 x Raj 4079 | 1.01 | 1.10 | 0.89 | 0.96 | 0.41 | 1.44 | 1.26 | 1.20 | 1.70 | 1.24 | 0.75 | 0.69 | 1.42 |
| Raj 3765 x PBW 550 | 1.04 | 1.05 | 0.28 | 1.09 | 0.36 | 1.13 | 1.59 | 0.98 | 2.29 | 1.93 | 1.82 | 0.95 | 1.65 |
| Raj 3765 x HI 1563 | 0.46 | 1.31 | 1.04 | 0.95 | 0.70 | 0.76 | 1.28 | 1.30 | 1.15 | 0.93 | 0.64 | 0.93 | 0.62 |
| Raj 3765 x Raj 4079 | 1.26 | 0.26 | 0.86 | 0.74 | 1.14 | 0.83 | 0.69 | 0.94 | -0.42 | 0.09 | 0.17 | -0.08 | 0.43 |
| PBW 550 x HI 1563 | 0.68 | 1.17 | 0.81 | 1.42 | 1.63 | 1.71 | 1.51 | 1.54 | 0.31 | 0.54 | 0.74 | 1.53 | 1.86 |
| PBW 550 x Raj 4079 | 1.03 | 1.03 | 0.40 | 1.04 | 0.47 | 1.45 | 1.26 | 1.60 | 3.28 | 1.94 | 0.46 | 1.29 | 0.99 |
| HI 1563 x Raj 4079 | 1.02 | 1.23 | 1.06 | 1.12 | 1.36 | 2.09 | 0.95 | 1.22 | 0.06 | 1.06 | 1.95 | 1.68 | 1.28 |

## Conclusion
The result of heat susceptibility index (HSI) exhibited that parents *viz.*, UP 2425, PBW 502, Raj 4037 and Raj 4079 were desired for grain yield and some other traits. Among the crosses, DPW 621-50 x Raj 4037 and DBW 90 x Raj 4037 were found more desirable for heat tolerance in most of the studied traits across the generations may be used as promising breeding material for development for heat stress tolerant wheat cultivars.

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