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Research Article

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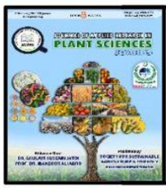

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General Combining Ability and Specific Combining Ability Analysis for Terminal Heat Tolerance in Wheat (*Triticum Aestivum* L.)

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Abstract

Developing bread wheat genotypes for terminal heat tolerance is a critical objective for future breeding approaches. The line x tester mating analysis is one of the best approaches to demonstrate the appropriateness of the bread wheat genotypes for selection breeding programs. For this purpose, nine genotypes viz. T.J-83, NIA Sarrang, Khirman, SKD-1, Sehar-2006, Sarsabaz, AS-2002, NIA-Amber, and Nifa Barsat were used in this research. The experiment was planned in a factorial design with two treatments (normal and heat stress) at Botanical Garden Farm, Sindh Agriculture University Tandojam, during 2019-2020. The results depicted that at terminal heat stress, the genotypes were significantly affected by yield and physiological traits at late sowing. During the initial screening, the female parents, T.J-83, Sarsabaz, and Nifa Barsat executed very well under heat stress conditions for nearly all the yield and morphological traits. Similarly,the male parents such as Khirman and SKD-1 also performed well under heat stress conditions for all traits compare to the female parents. Furthermore, through genetic analysis, the mean effects of General Combining Ability (GCA) and Specific Combining Ability (SCA) were significant for all the characters signifying that additive and non-additive variances are important. Further, in heat-stress environments, the GCA was dominant for most characters in contrast to SCA variations. Hence, in this study, under both normal and heat stress conditions, Khirman and SKD-1 proved to be better general combiners for various characters. Therefore, these genotypes are recommended as vigor parents for hybridization and selection programs as emerging terminal heat stress tolerant genotypes.

Keywords: *Line x tester, heat stress, bread wheat, Morphological traits, GCA and SCA.*

Introduction

Triticum aestivum (L.), is a member of the Poaceae family, is widely regarded as the principal cereal staple crop of many nations. It is grown under both irrigated and rain-fed conditions, is classified as a domesticated, self-pollinating crop, and has played a significant role in the development of numerous diverse domesticated wheat varieties (Ijaz *et al*., 2015). Wheat is a staple food of a huge human population globally consumed, processed and refined (Bhutto *et al*., 2021). Bread wheat provides approximately 70% of calories and 80% of protein (Ahmed *et al*., 2022). During 2020-21, the cultivation of wheat decreased 2.1 percent as 8,976 thousand hectares against last years's sown of 9,168 thousand hectares. The production of wheat declined to 26.394 million tonnes (3.9 percent) compared to 27.464 million tonnes production of last year. Wheat production declined due to decline in area sown, shortfall in irrigation water and drought conditions at sowing, less fertilizers offtake and heat wave in March/April, Wheat crop recorded high prodcuction of 27.293 million tonnes showing an increase of 8.1 percent over 25.248 million tonnes production of last year (GoP, 2021-2022). For a wheat breeding effort to be successful, there must be evidence of General Combining Ability (GCA), Specific Combining Ability (SCA), and gene action in the breeding material. the line-tester analysis technique Kempthorne first proposed (1957) who described the technique as one of the effective strategies for evaluating the effects of combining ability while choosing desired parents and crosses for pedigree manipulation (Jain and Sastry, 2012). While specialized combining ability is an assignment tool that aids in predicting non-additive type gene actions, general combining ability is a tool to aid in evaluating the additive type of gene effects. Also, it is believed that additive gene actions or complementing episttic gene interactions are reliable and unfixable, whereas non-additive gene actions are not (Iqbal *et al*., 2017). To produce effective genotypes against heat stress, a breeding programme must develop heat tolerant and high yielding genotypes (Moustafa *et al*., 2021). One of the crucial biometrical methods to evaluate the impacts of general (GCA) and specialised (SCA) combining abilities and to identify the genes responsible for different features is the diallel mating design (Saleem *et al*., 2020). The best parents and their cross-combinations for producing superior offspring when breeding for heat tolerance can be found using the GCA and SCA effects (Kamara *et al*., 2021).

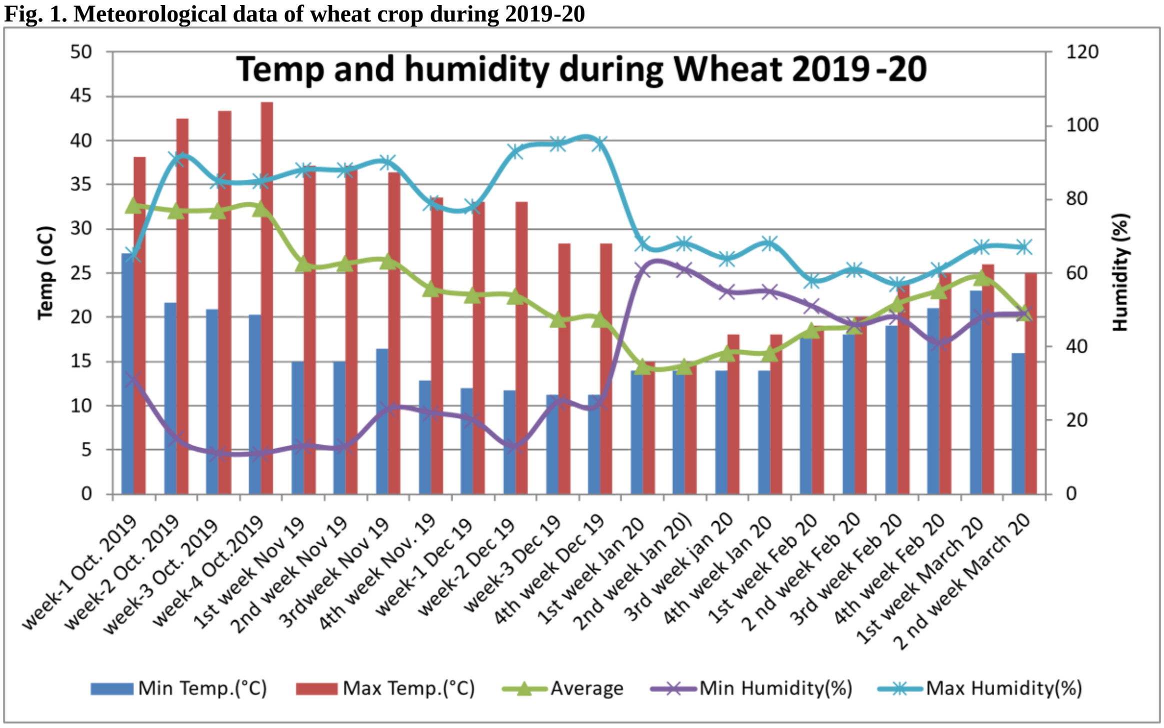
Selection is based on morphological and physiological characteristics related to heat stress performance (Khan *et al.*, 2015). Tolerance metabolism has been observed in chlorophyll, leaf senescence, photosynthetic rate and temerature (Moustafa *et al.*, 2021). The relationship between morpho-physiological traits with heat tolerance is vital for selecting suitable genotypes against heat stress (Khan *et al.*, 2015; Poudel *et al.*, 2021). Keeping in view the foregoing, the main goal of the current study is to find general and specific combining ability, among varietal yield in F_1 hybrid genotypes, based on morpho-physiological features, in order to generate a new productive, heat-tolerant and high yielding variety. The current study used the line x tester approach to assess wheat genotypes for heat stress resistance at the terminal stage based on morpho-physiological features. Determine the combining capacities (GCA and SCA) of parental genotypes and F_1 hybrids under heat stress was the goal of our investigation.

Materials and Methods

The present research was carried out at the Experimental Field, Department of Plant Breeding & Genetics, Sindh Agriculture University, Tandojam. The experiment was laid-out in two successive Rabi season's 2019 and 2020. The plant material used in this study comprised of seven diverse wheat genotypes, including four tolerant and three susceptible to heat stress. The tolerant genotypes were selected based on their superior performance under heat stress, while the susceptible ones were selected from commercial varieties commonly grown in the region. The design used was Factorial Design (RCBD) with three replications. In this context, the experimental materials were evaluated in two sowing dates i.e. normal planting (25th November) and late planting (25th December). The experimental details are as under. The investigation was conducted at Botanical Garden, Department of Plant Breeding and Genetics, Sindh Agriculture University, Tando Jam.

Meteorological condition: The main meteorological factors such as weekly distribution of rainfall, minimum and maximum temperature and relative humidity recorded through meteorological observatory of Nuclear Institute of Agriculture (NIA), for the period of investigation are presented in graphically for the year 2019-20 in Fig.1.

Fig. 1. Meteorological data of wheat crop during 2019-20



Temperature during the experimental period: The temperature during the entire wheat season was found to be variable and wide range of differences observed for all the traits under both sowing dates (Fig.1). High temperature of 44^0 C persisted on 27th October during the third week of November. The temperatures from December till March were relatively favorable for wheat crop planted in normal condition (November 20th), while low and high temperature during anthesis and grain formation stage were not suitable as crop planted in late December (20th) (Fig.1). Moderately high temperatures (20°C-25°C) were recorded during the 2nd week of February (15 days after anthesis) until the 4th week of February. The temperature increased in March until the 20th, reaching 29°C. Disastrous temperatures were observed in the end of March and the month of April (>40°C).

Morphological parameters: The morphological characters studied were days to 75% heading, days to 75% maturity, plant height (cm), number of productive tillers, spike length spike^{-1} (cm), number of spikelets spike$^{-1,}$ number of spikelets spike^{-1}, grains yield plant^{-1} (g), and seed index (weight of 1000 grains in g)

Statistical analysis: Line x tester analysis: The experimental data obtained on 13 characters were subjected to analysis of variance (Gomez and Gomez, 1984). After testing the significance among the treatments and crosses, line x tester analysis for the estimation of combining ability was estimated.For the estimation of general and specific combining ability variances as outlined by Kempthorne (1957) was followed. Statistix 8.1 software was used for analysis.

Results

Wheat is a major crop consumed by half of the world population (Bhutto *et al*., 2021). During flowering and booting stages of wheat crops were more affected by heat stress (Yang *et al*., 2016; Mirosavljević *et al*., 2021). Hence, the present study was to work on lines and testers using general combining and specific combining abilities among varietal yield in F_1 hybrid genotypes.

Analysis of variance: The analysis of variance specified that heat stress treatments caused substantial effects on days to 75% heading, days to 75% maturity, plant height, number of productive tillers plant^{-1}, spike length ^{1}, number of spikelets spike^{-1}, grains weight plant^{-1}, grain weight spike^{-1}, grain yield plant^{-1}, seed index , biological yield plant^{-1}, harvest index, flag leaf area , relative water content, chlorophyll content, cell membrane stability and stomatal conductance (Tables-1). The F_1 hybrid cultivars also significantly varied in their performances for all the yield characters. The genetic variation of heat stress treatments x genotypes were observed for significant with the majority of the characters including days to 75% heading, days to 75% maturity , number of productive tillers plant^{-1}, plant height, spike length, number of spikelets spike^{-1}, grain yield plant^{-1}, biological yield plant $^{-1}$, harvest index, seed index , relative water content, flag leaf area, chlorophyll content, cell membrane stability and stomatol conductance indicating that varities behaved differntly under heat stress circumstances (Table 1).

GCA and SCA affects of various morphologcal characters under heat stress Days to 75% heading: This character showed that higher negative GCA effects were observed in parents leading to a decline in the number of days to 75% heading in non-heat stress conditions, with T.J-83 (-2.08), Nifa Barsat (-1.49), Khirman (-0.76), Sarsabaz (-0.59), and SKD-1 (-0.14). Similarly, under heat stress, negative GCA effects were established, resulting in a reduction in days to 75% heading compared to the parents, with T.J-83 (-1.14), Khirman (-0.41), Sarsabaz (-0.38), SKD-1 (-0.35), and Nifa Barsat (-0.33). T.J-83 (-1.14), Khirman (-0.41), Sarsabaz (-0.38), SKD-1 (-0.35) and Nifa Barsat Barsat(-0.33) were also established. Nevertheless, parent, T.J.-83 (-2.08) and NIFA -Barsat showed the greatest GCA impacts in reducing days to 75% heading (-1.40). The parents with negative GCA effects against, T.J-83, NIFA-Barsat, Khirman, Sarsabaz, and SKD-1 were recorded as the best heat tolerant parents (Table 2*)*. In F_1 hybrids, the higher negative effects of SCA in terms of reduction in dyas to 75% heading earlier were recorded for T.J-83 x Khirman (-2.54), T.J-83 x SKD-1 (-1.21), Sarsabaz x Khirman (-1.02), Nifa Barsat x Khirman (-0.98), Nifa Barsat x SKD-1 (-0.85) and Sarsabaz x SKD-1 (-0.74) while in heat stress, the effects of SCA in terms of reduction in days to 75% heading earlier were demonstrated for T.J-83 x Khirman (-1.11), T.J-83 x SD-1 (-0.93), Sarsabaz x Khirman (-0.65), Sarsabaz x SKD-1 (-0.57), Nifa Barsat x Khirman (-0.55) and Nifa Barsat x SKD-1 (-0.16). However, the maximum SCA effects was recorded for T.J-83 x Khirman (-2.54) while lower SCA effects was recorded for Sarsabaz x SKD-1 (-0.74) under non-heat stress. SCA ffects in terms of earlier heading T.J-83 x Khirman, T.J-83 x SKD-1, Sarsabaz x Khirman, Nifa Barsat x Khirman and Nifa Barsat x SKD-1 were recorded as the best heat tolerant wheat hybrids in (Table-3).

Days to 75% maturity: The parental lines, T.J-83, Nifa Barsat and Sarsabaz were recorded with negative but higher GCA effects of -1.72, -1.53 and -1.03 days to 75% maturity earlier respectively followed by Khirman (-0.87) and SKD-1(-0.80) in non-stress condition. Similarly, the parents, T.J-83, Sarsabaz and Nifa Barsat responded negatively with higher GCA influences of -0.78, -0.74 and -0.71 days respectively in heat stress environments. The GCA effects against T.J-83 and Sarsabaz were higher in non-stress condition than in heat stress environment (Table 1). The parents, T.J-83, Nifa Barsat Barsatand Sarsabaz were recorded as the three high scorers among the parents for days to 75% maturity with higher GCA effects by reduction of -1.72, -1.53 and -1.03 days under non-heat stress while under heat stress conditions were observed with the GCA effects of -0.78, -0.74 and -0.71 days respectively (Table 2).The

SCA effects in F_1 hybrids showed maximum in T.J-83 x Khirman (-1.09), T.J-83 x SKD-1(-1.07) and Sarzabaz x Khirman (-0.96) followed by Sarsabaz x SKD-1 (-0.86), Nifa Barsat x Khirman (-0.56) and Nifa Barsat x SKD-1 (-0.41) in control.. Similarly, the hybirds, T.J-83 x Khirman (-0.74), T.J-83 x SKD-1 (-0.72), Sarsabaz x Khirman (-0.49), Sarsabaz x SKD-1 (-0.45) Nifa Barsat x Khirman (-0.40) and Nifa Barsat x SKD-1 (-0.23) also obtained higher SCA effects under heat stress environment in (Table 4). The negative SCA effects was observed in Nifa Barsat x SKD-1 (-1.09), T.J-83 x SKD-1 (-1.07) and T.J-83 x Khirman (-0.96) and heat stress environments. (Table 4).

Plant height (cm): The parental lines, T.J-83 (-2.31), Nifa Barsat (-1.99), Sarsabaz (-1.87), Khirman (-0.850 and SKD-1 (-0.78) received higher negative GCA effects (Table 1). Similarly the parents, NIFA-Barsat, Sarsabaz and T.J-83 displayed higher negative GCA effects in terms of reduction with height of -1.11, -1.10, and -0.59 cm in eat stress, respectively. The parents who showed stronger GCA effects in reduced plant height under both conditions could be suggested as the heat stress tolerant (Table 2). For SCA effects, the hybrids, T.J-83 x Khirman (-2.96),T.J-83 x SKD-1 (-2.00), Sarsabaz x Khirman (-1.91), Sarsabaz x SKD-1(-1.64), Nifa Barsat x Khirman (-1.47) and Nifa Barsat x SKD-1(-1.38) while hybrids, T.J-83 x x Khirman (-1.46), T.J-83x SKD-1 (-1.02), Sarsabaz x Khirman (-0.80), Sarsabaz xSKD-1 (-0.74) Nifa Barsat x Khirman (-0.37) and Nifa Barsat x SKD-1 (-0.37), exhbited higher negative SCA effects in both, control and heat stress conditions, respectively (Table 4). Among these six hybrids, T.J-83 x Khirman, T.J-83 x SKD-1, Sarsabaz x Khirman, Sarsabaz x SKD-1, Nifa Barsa tx Khirman and Nifa Barsat x SKD-1 and while hybrids, T.J-83 x Khirman, T.J-83 x SKD-,1 Sarsabaz x Khirman, Sarsabaz x SKD-,1 Nifa Barsat x Khirman and Nifa Barsat x SKD-1 displayed higher negative SCA effects (Table-4).

Number of productive tillers plant^{1}: The maximum positive GCA effects of 1.02 was expressed by the parent Nifa Barsat Barsat followed by Sarsabaz (0.55) and SDK-1(0.52) for the number of productive tillers plant^{-1} in normal condition, while the same parents also presented higher GCA effects of 1.08, 0.82 and 0.59 in heat stress, respectively. The parent, T.J-83, noticed that the amount of GCA impacts was larger under heat stress as compared to non-heat stress and recorded 0.35 tillers plant^{-1} (Table 2). SCA effects was expressed maximum in the hybrids, T.J-83 x Khirman (1.32), T.J-83 x SKD-1(1.17), Sarsabaz x Khirman (1.14), Sarsabaz x SKD-1 (1.11) followed by Nifa Barsat x Khieman (0.19) and Nifa Barsat x SKD-1(0.18) for the number of productive tillers plant^{-1} in non-stress while the same F_1 hybrids also presented greater positive SCA effects by T.J-83x Khirman, T.J-83 x SKD-1, Sarsabaz x Khirman, Nifa Barsat x Khirman, Sarsabaz x SKD-1 and Nifa Barsat x SKD-1 with values of 0.91, 0.76, 0.71, 0.64, 0.59 and 0.45 numbers of tillers plant^{-1} under heat stress condition respectively (Table 4).

Spike length (cm): Among the nine parental lines studied, four lines showed negative GCA effects while others displayed positive GCA effects. All the desirable parents demonstrated positive GCA effects in non-heat stress and heat-stress as well (Table 1). Though, T.J-83 (0.69cm), Nifa Barsat Barsat(0.66cm), Sarsabaz (0.53cm), Khirman (0.42cm) and SKD-1 (0.31) showed higher GCA effects in non-heat stress whereas the same parents also counted maximum GCA effects of 0.92, 0.64, 0.63, 58 and 0.30cm for T.J-83, NIFA-Barsat, Khirman, Sarsabaz and SKD-1 in heat stress environment respectively. During investigation, the GCA effects were prominent for some parents for spike length under heat stress condition for this trait.(Table 2). T.J-83 x Khirman (0.98cm), Sarsabaz x Khirman (0.89cm), T.J-83 x SKD-1 (0.84 cm), Sarsabaz x SKD-1 (0.83cm), Nifa Barsat x Khirman (0.79cm), and Nifa Barsat x SKD-1 (0.43) showed higher positive SCA effects in non-heat stress whereas the same F_1 hybrids, T.J-83 x SKD-1, Sarsabaz x Khirman, T.J-83 x SKD-1, T.J-83 x Khirman, Sarsabaz x SKD, Nifa Barsat x Khirman and Nifa Barsat x SKD-1 also regarded the maximum SCA effects of 1.27, 1.08, 1.04. 0.95, 0.88, and 0.60cm for spike length in heat stress condtions, respectively (Table 4).

Number of spikelets spike^{-1}: Almost all the parents showed positive GCA , while four of them exhibited positive but four regarded as negative GCA effects, nevertheless, the highest GCA effects were recorded by T.J-83 (0.95) followed by Nifa Barsat (0.93), SKD-1 (0.80), Sarsabaz (0.30) and Khirman (0.11) for number of spikelets spike^{-1} in non-stress, whereas T.J-83 was categorized as 1st with positive GCA effects of 1.23 followed by Nifa Barsat 0.99), SKD-1 (0.76), Sarsabaz (0.61) and Khirman (0.28) in heat stress conditions (Table 2). The GCA effects at large were greater in heat stress than non-heat stress (Table 3). From nine F_1 hybrids, six exhibited positive while three regarded as negative SCA effects, nevertheless, the highest SCA effect was recorded for T.J-83 x Khirman (1.56) followed by T.J-83 x SKD-1 (1.07), Sarsabaz x Khirman (1.02), Sarsabaz x SKD-1 (0.80), Nifa Barsat x Khirman (0.75) and Nifa Barsat x SKD-1 (0.51) for number of spikelets spike^{-1} in non-stress, whereas T.J-83 x Khirman (1.30) and T.J-83 x SKD-1 (1.20) followed by Sarsabaz x Khirman (0.94), Sarsabaz x SKD-1(0.87), Nifa Barsat x Khirman (0.86) and Nifa Barsat x SKD-1 (0.53) were categorized as 1st cross combinations in heat stress condition in the (Table 5).

Number of grain spike^{-1}: The highest positive GCA influences of 3.05 were recorded against the number of grains spike^{-1} for the parent, T.J-83 followed by Nifa Barsat Barsat(2.15), Sarsabaz (1.05), SKD-1 (0.61) and Khirman (0.59) in non-stress while in heat stress, the same parent, T.J-83 also ranked as 1st by receiving the highest GCA effects of 4.07, whereas in heat stress environment, the parents, Nifa Barsat (2.85), Sarsabaz (2.14), SKD-1 (1.24) and Khirman (1.21) classified as the second, third, fourth, and fifth category parents, accordingly (Table 2). In general, it is found that parents under heat stress experienced greater positive GCA impacts on the number of grains spike-1 compared to non-stress environment (Table 3). The highest positive SCA effects of 2.25 were scored by the F_1 hybrid, T.J-83 x Khirman followed by T.J-83 x SKD-1 (2.24), Sarsabaz x Khirman (2.00), Nifa Barsat x Khirman (1.31), Sarsabaz x SKD-1 (1.23) and Nifa Barsat x SKD-1 (1.22) for number of grains spike^{-1} in non-stress whereas in heat stress, the F_1 hybrids, T.J-83 x Kkhirman (3.09), T.J-83 x SKD-1 (2.37), Sarsabaz x Khirman (2.29), Sarsabaz x SKD-1 (2.29), Nifa Barsat x Khirman (1.53) and Nifa Barsat x SKD-1 (1.17) showed highest SCA effects for number of grains spike^{-1}. The F_1 hybrids, T.J-83 x Khirman was marked as 1st by performing the highest positive SCA effects of 3.09 number of grains spike^{-1} in heat stress condition, while the other F_1 hybrids, T.J-83 x SKD-1 (2.37), Sarsabaz x Khirman (2.29), Sarsabaz x SKD-1 (2.29), Nifa Barsat x Khirman (1.53) and Nifa Barsat x SKD-1 (1.17) were also identified as 2nd, 3rd, 4th and 5th respectively by performing better during heat stress condition in the (Table 5).

Grain weight spike^{-1} (g): The values are shown in Table 2 after the GCA effects were proven for the grain weight spike-1 versus the non-heated and heat-stressed parents. Under non-heat stress conditions, the parent, NIFA-Barsat, gave the greatest GCA effects (0.32g grain weight spike-1), followed by T.J-83 (0.29g), Sarsabaz (0.29g), Khirman (0.16g), and SKD-1 (0.14g). Moreover, under conditions of heat stress, the same parent, NIFA-Barsat, was also ranked first by exhibiting the highest GCA effects of 0.3g grain weight spike-1, ahead of the parents T.J.-83 (0.32g), Sarsabaz (0.30g), Khirman (0.17g), and SKD-1 (0.17g) (0.17g) were categorised as parents in the second, third, and fourth categories, and they may each be employed for additional breeding. In short, it has been found that parents reported increased favourable GCA impacts on the increase of spike-1 grain weight in heat stress environments. Nonetheless, Table 2 summarises the significant but adverse GCA effects that were seen in the parents. Amongst the F_1 hybrids, T.J-83 x Khirman showed maximum SCA effects of 0.32 grain weight spike^{-1} followed by T.J-83 x SKD-1 (0.28), Sarsabaz x Khirman (0.24), Sarsabaz x SKD-1 (0.16), Nifa Barsat x Khirman (0.14) and Nifa Barsat x SKD-1 (0.14) under non-heat stress whereas the remaining F_1 hybrids bared negative SCA effects. Further that in heat stress, the same hybrid, T.J-83 x Khirman was marked as 1st by expressing the highest SCA effects of 0.34 grain weight spike^{-1} followed by T.J-83 x SKD-1 (0.30), Sarsabaz x Khirman (0.29), Sarsabaz x SKD-1 (0.18), Nifa Barsat x Khirman (0.17) and Nifa Barsat x SKD-1 (0.15) were classified as 2nd, 3rd, 4th and 5th ranking hybrids for further breeding programmes respectively (Table 5).

Grain yield plant^{-1} (g): Five parents were responded positively to GCA effects regarding the grains weight plant^{-1} while the remaining parents were recorded as negative response to GCA (Table 2). Within the parents, Sarsabaz contributed maximum to GCA effects of 1.06g, followed by Nifa Barsat (0.81g), SKD-1 (0.56g), Khirman (0.17g) and T.J-83 (0.14g) whereas the left-over parents expressed negative effects in non-stress environment. However, in heat stress condition, the parent, Sarsabaz exhibited the highest GCA effects of 1.09g, grains yield plant^{-1} followed by Nifa Barsat Barsat(0.78g), SKD-1(0.58g), T.J-83 (0.30g) and Khirman (0.17g) while other parents showed significant negative GCA effects for the trait. Eighteen hybrids investigated, nine were responded positively to SCA effects regarding the grain weight plant^{-1} while remaining hybrids were recorded as negatively inherited to SCA (Table 5). Within F_1 hybrids, T.J-83 x Khirman acknowledged maximum SCA effects (1.31g) followed by T.J-83 x SKD-1 (0.88g), Sarsabaz x Khirman (0.72g), Sarsabaz x SKD-1 (0.66g), Nifa Barsat x Khirman (0.52g) and Nifa Barsat x SKD-1 (0.50g) whereas the lingering F_1 hybrids expressed negative SCA effects in non-stress environment. However, in heat stress, the F_1 hybrid, T.J-83 x Khirman exhibited the highest SCA effects (1.25g) followed by T.J-83 x SKD-1 (0.90g), Sarsabaz x Khirman (0.74g), Sarsabaz x SKD-1 (0.54g), Nifa Barsat x Khirman (0.54g) and Nifa Barsat x SKD-1 (0.52). It was observed from the pressent performances of the hybrids that the SCA effects were lower in-non heat stress than the heat stress environments for grain yield plant^{-1} (Table 5).

Seed index (%): Out of 9 parents, 5 showed positive while four recorded as negative GCA influences in non-heat stress and heat stress environments Table 2. Though, the parents, NIFA-Barsat, T.J-83, Sarsabaz, Khirman and SKD-1 presented positive GCA effects with values of 1.68, 1.40, 0.97, 0.56 and 0.37% seed index in non-heat stress condition respectively whereas in heat stress circumstance, the ranking order of Nifa Barsat Barsatwas further improved, remained stable and recorded as the first with 1.71% seed index followed by T.J-83 (1.37%), Sarsabaz (1.14%), SKD-1 (0.57%) and Khirman (0.51%). The remaining parental lines displayed notable, detrimental GCA effects. It was determined that the parent, NIFA-Barsat, was a good combiner for the trait. A strong GCA number in the positive direction indicates good overall combining ability because 1000 grain weight is a significant indirect selection factor for grain production. F_1 hybrid, Sarsabaz x Khirman demonstrated maximum SCA effects against seed index value of 1.74% followed by T.J-83 x Khirman (1.52%), T.J-83 x SKD-1 (1.20%), Sarsabaz x SKD-1 (1.14%), Nifa Barsat x Khirman (0.74%) and Nifa

Barsat x SKD-1 (0.56%) exhibited positive SCA effects in non-heat stress whereas in heat stress, the ranking level of T.J-83 x Khirman was further improved and remained stable and regarded as first with 1.85% seed index trailed by T.J-83 x SKD-1 (1.46%), Sarsabaz x Khirman (1.11%), Sarsabaz x SKD-1 (1.09%), Nifa Barsat x Khirman (0.83%) and Nifa Barsat x SKD-1(0.65%) (Table 6).

Biological yield plant^{-1} (g): Among the parents, the effects of GCA were observed against the biological yield plant^{-1} throughout current analysis and figures are demonstrated in Table 3. The parents, NIFA-Barsat, Sarsabaz, T.J-83, SKD-1 and Khirman received positive GCA effects and yielded as 1.63, 1.26, 1.14 0.54 and 0.46g biological mass plant-1 under non-heat stress condition respectively. Furthermore, under non-heat stress condition, only four parents did acknowledge negative response to GCA. Similarly, the parents showed better response to GCA under non-heat stress were also showed highest positive GCA effects under heat stress environments as compared to non-stress and yielded 1.74, 1.68, 1.61, 0.68 and 0.98g biological yield plant^{-1} respectively (Table 3). UP-2425, WH-1105, UP-2672, and WH-1139 were among the parental lines that showed substantial positive GCA effects with values of 3.59, 2.22, 1.84, and 1.33g, respectively, when 17 parents were tested for GCA impacts against biological yield plant-^{1}. The F_1 hybrids, T.J-83 x Khirman, T.J-83 x SKD-1, Sarsabaz x Khirman, Sarsabaz x SKD-1, A.Barsat x Khirman and A-Barsat-x SKD-1 received positive effects of SCA and yielded 1.39, 0.90, 0.75, 0.71, 0.66 and 0.23g biological yield plant^{-1} under non-heat stress respectively. Whereas under the same condition, majority of the outstanding hybrids did acknowledge negative response to SCA. Likewise, the hybrids showed better performances under SCA effects in heat stress as compared to non-stress and displayed highest positive SCA effects of 2.44, 1.41, 1.37, 1.28, 1.00 and 0.59g as biological yield plant^{-1} by hybrids, T.J-83 x Khirman, T.J-83 x SKD-1, Sarsabaz x Khirman, Sarsabaz x SKD-1, Nifa Barsat x Khirman and Nifa Barsat x SKD-1 respectively in the (Table 6).

Harvest index (%): of the nine parents studied for GCA response, five of them like, T.J-83 (1.58%), Sarsabaz (0.73%), SKD-1 (0.58%), Nifa Barsat Barsat(0.27%) and Khirman (0.24%) responded positively to GCA in non-heat stress while other parents showed negative response to GCA.(Table 3). Alike, the parents performed well in the presence of GCA under non-stress condition were also exhibited three times more pronouncedly to GCA influences in heat stress condition. Furthermore, that irrespective of other four parents recorded positively to GCA effects in both, non-heat and heat stress situations, the parent, T.J-83 was only the parent that acknowledged the highest (2.02%) GCA effects under heat stress condition followed by Sarsabaz (1.26%). Nifa Barsat Barsat(1.08%), Khirman (0.76%) and SKD-1 (0.71%) are identified as good combiners for the trait. the eighteen F_1 hybrids studied for harvest index under SCA response, six crosses, T.J-83 x Khirman (1.82%), Sarsabaz x Khirman (1.31%), T.J-83 x SKD-1 (1.24%), Sarsabaz x SKD-1 (0.66%), Nifa Barsat x Khirman (0.64%) and Nifa Barsat x SKD-1 (0.51%) responded positively to SCA effects in non-heat stress situation while other F_1 hybrids showed least positive and negative responses to SCA.effects (Table 6).

Discussion

For heat stress-tolerant, the General Combining Ability (GCA) and Specific Combining Ability (SCA) are important brreding techniques. In the current study, mean squares for GCA and SCA were significant for morphological and yield traits in the stress and non-stress treatments, demonstrating that parents responded differentially to the heat stress conditions for several traits. Whereas, Xu *et al.*, 2022 studied significant results for five parental lines, our result showed that parent, WH-1139 (-1.167) exhibited highest significant negative GCA effect for days to 75% heading (Table1). Similarly, noteworthy outcomes for the line x tester cross for grain yield in wheat have been reported by Mirosavljević *et al*., 2021 (*Triticum aestivum* L.). Certain parental lines during the current study shown favourable GCA effects (Table 1). However, few lines considered to be highly desirable exhibit significant negative GCA effects. Similarly, Tabassum *et al*., (2017) claimed that PBW681 may be regarded as a good general combiner for dwarf-ness due to their respective strong positive GCA impacts. However, certain parental lines showed significant positive GCA benefits, whilst others showed significant negative GCA effects (Table 1). According to Hassan *et al*., (2021) and Deniz *et al*., (2015) reported that the number of tillers among the lines showed positive effects on heat tolerance. Bhalerao *et al*., 2020. after the GCA demonstrated significantly beneficial impacts on the number of tillers among the lines (1.62). Our results showed that spike length is one of the major yield-contributing traits (Table 1).

The current findings on the parental lines' showed a significant beneficial GCA impact against the number of spikelets spike^{-1}. Hassan *et al*. (2021) and Bhalerao *et al*., 2020 (Table 2), the number of grains spike^{-1} exhibited strong favorable GCA effects (Table 2). As a result, the conclusions of the aforementioned authors are closely supported by the current observations, which show considerable GCA impacts against the number of grains spike$^{-1.}$. Positive GCA values indicate prospective parents since grain weight spike^{-1} is a desired yield subsidizing in our research. A strong combiner for the trait was found in the line Sarsabaz. Hassan *et al*. (2021) noted substantial favorable GCA impacts against lines HTSBWON-15-0029 (0.19g), HTSBWON-15-0040 (2.20g), HTSBWON-15-0079 (0.81g), and Faisalabad-08

(0.18g) in the grains yield plant^{-1} study (Table 2). The results of the present study are in close confirmation with the earlier observations made by Kapoor *et al.*, 2011. Bhalerao 2020 stated that parents presented different degrees and magnitudes of GCA effects under heat stress for the trait. Among the lines, AKW-1071 (1.64%), AKAW-4927 (1.19%), PDKV-Sardar (0.49%), and AKAW-4627 (0.3%) were recognized as good general combiners for 1000 grains weight in the (Table 2). The harvest index for GCA effects was reported similar to the effects of GCA against the yield by Hassan *et al*., 2021 (Table 3).

Additionally, Mirosavljević *et al.*, 2021 *et al*. (2017) reported similar findings regarding the SCA effects for days to 75% heading (Table-4). Moreover, Kamara *et al*., 2021 investigated the impact of SCA on the number of days till heading under a late sowing date. The crosses P2 x P6 (-0.84), P1 x P4 (-0.76), and P4 x P6 (-0.59) demonstrated SCA effects in early days to 50% heading due to late sowing in the P3 x P5 and P4 x P5 crossings, respectively, displayed substantial negative SCA effects in a decrease of days to heading earlier (Table 4). However, Bhalerao *et al*., 2020 reported findings that were equivalent to those of this investigation, including negative SCA effects.The present study's findings about the impact of SCA on the reduction of days to 75% maturity against F_1 hybrids are consistent with those of the aforementioned researchers for the trait (Table 4). Kamara *et al*. (2021) reported SCA impacts on plant height and features associated with bread wheat in both hot and normal conditions. Only five of the sixteen crosses under investigation P1 x P3, P2 x P5, P3 x P4, P3 x P6, and P3 x P exhibited highly significant negative SCA effects. Other crosses showed substantial and non-significant negative SCA effects, including P4 x P5, P2 x P6, and P4 x P6, as well as P1 x P2 and P2 x P6. Bhalerao *et al*. (2020) had similar research documented SCA's impact on contributing characteristics in wheat during heat stress (Table 4). Both highly s Hassan *et al* (2021) counted significant positive SCA effects for the number of productive tillers plant^{-1} in crosses that varied from 0.28 to 2.72 under heat stress condition. Whereas, Bhalerao *et al.*, 2020 reported significant and no-significant positive SCA effects, for number of productive tillers. Majority of the crosses showed positive SCA effects with number of tillers plant^{-1} those ranged from 0.027 to 2.439 tillers plant^{-1} (Table-4). These results are consistent with those from other studies that found SCA effects for the same trait, including Hassan *et al*., 2021; Bhalerao *et al*., 2020; and Tabassum *et al*., (2017)(Table-4).

Yet, the computation of combining ability estimations in heat-stressed bread wheat yielded equal outcomes in their F_1. The crosses demonstrated notable favorable SCA effects for the spikelet with the most spikelets, spile^{-1}. Tabassum *et al*., (2017); Bhalerao *et al*., (2020); Hassan *et al*., (2021) who counted the same crosses under SCA effects as indicated in this work noticed comparable results (Table 5.). The number of grains spike^{-1} the crosses was reported by Hassan *et al*., 2021,having substantial positive SCA effects. Out of eighteen hybrids investigated, nine responded positively to SCA effects regarding the grain weight plant^{-1} (Table 5). The hybrid's performance revealed that in grain yield plant^{-1}, the SCA effects were less in normal condition. Bhalerao *et al*. (2020) found that grain yield plant^{-1} had a substantially favorable SCA effect in comparison to the crosses. Moreover, (Hassan *et al*., 2021) revealed outcomes that were comparable to those shown for crosses in this investigation. Naturally all these could be grown further as heat stress tolerant hybrids. Similar study was conducted by Hassan *et al.*, 2021 to know the SCA effects on 1000 grain weight agaisnt crosses under heat stress condition. Furthermore that the present results are also in close agreement to the findings of (Bhalerao *et al.*, 2020;Tabassum *et al.*, 2017).

In the F_1 hybrids, the SCA effects were observed against the biological yield plant^{-1} during current investigation (Table 6). Moreover, at same time the authors also recorded significant higher positive and negative SCA effects against biological yield plant^{-1} (Table 6). The F_1 hybrids, T.J-83 x Khirman, T.J-83 x SKD-1, Sarsabaz x Khirman, Sarsabaz x SKD-1, A.Barsat x Khirman and A-Barsat-x SKD-1 received positive effects of SCA and yielded 1.39, 0.90, 0.75, 0.71, 0.66 and 0.23g biological yield plant^{-1} under normal condition, respectively. Likewise, the hybrids showed better performances under SCA effects in heat stress as compared to non-stress and displayed highest positive SCA effects of 2.44, 1.41, 1.37, 1.28, 1.00 and 0.59g as biological yi d plant^{-1} by hybrids, T.Jthe -83 x Khirman, T.J-83 x SKD-1, Sarsabaz x Khirman, Sarsabaz x SKD-1, Nifa Barsat x Khirman and Nifa Barsat x SKD-1 respectively. The F_1 hybrid, T.J-83 x Khirman was only the hybrid that acknowleged the highest harvest index (1.72%) to SCA effects under heat stress condition followed by T.J-83 x SKD-1 (1.54%), Sarsabaz x Khirman (1.29%), Nifa Barsat x Khirman (1.05%) and Nifa Barsat x SKD-1 (.0.76%) (Table 6). However, some variable SCA effects against the crosses for harvest index were demonstrated by Tabassumm *et al*. (2017). Furthermore, the other hybrids remained positive SCA effects under heat-stress

Table 1 Analysis of variance of F_1 hybrids for morphological and yield traits obtained through crossing by 6 lines and 3 testers of bread wheat grown under non-heat stress and heat stress conditions

Sources of variance	D.F	Days to 75% heading	Days to 75% maturity	Plant height (cm)	Number of productive tillers plant^{-1}	Spike length (cm)	Number of spikelets spike^{-1}	Number of grain spike^{-1}	Grain weight spike^{-1} (g)
Replications	2	4.53**	22.51**	30.36**	26.94**	27.650**	28.48**	4.69**	0.004**
Genotypes	26	85.19**	781.19**	171.94**	5.958**	9.544**	10.93**	296.93**	4.525**
Parents	8	12.418**	26.621**	70.390**	4.82**	3.56**	13.77**	247.54**	0.173**
Hybrids	17	38.122**	129.99**	84.89**	19.76**	15.09**	16.19**	13.20**	0.70**
Parents versus Hybrids	1	1810.67**	19058.11**	3228.18**	41.699**	98.911**	44.542**	5620.248**	110.712**
Treatment	1	1682.26**	7349.84**	2598.40**	781.66**	372.384**	1514.15**	6538.47**	49.75**
Treatments x Genotypes	26	10.30**	74.71**	31.05**	12.404**	4.22**	4.06**	80.93**	0.369**
Lines	5	11.83**	13.13**	88.58**	4.81**	4.45**	19.43**	122.08**	0.058**
Testers	2	13.23**	4.47**	17.71**	6.89**	1.95**	6.47**	42.97**	0.123**
Lx T	10	12.42**	26.62**	70.39**	4.81**	64.33**	13.77**	247.54**	0.173**
Total error	161	3.54	1.09	1.97	0.980	0.97	1.07	4.53	0.002

**= significant at P<0.01probability level, *= Significant at P<0.05probability level

Table 2. The effects of general combining ability (GCA) on the parents for days to 75% heading , days to 75% maturity, plant height, number of tillers plant^{-1} and spike length spike^{-1} gown under non-heat-stress and heat stress conditions.

Parents	**Days to 75% heading**		**Days to 75% maturity**		**Plant height (cm)**		**No. of productive tillers plant^{-1}**		**Spike length**	
	Non-stress	Heat stress	Non stress	Heat stress	Non-stress	Heat stress	Non – stress	Heat stress	Non stress	Heat stress
TJ-83	-2.08	-1.14	-1.72	-0.78	-2.31	-0.59	0.35	0.58	0.69	0.92
Sehar-2006	0.61	-0.33	1.58	0.93	2.09	1.05	-0.50	-0.73	-0.54	-0.64
Sarsabz	-0.59	-0.38	-1.03	-0.74	-1.87	-1.10	0.55	0.82	0.53	0.58
AS-2002	1.21	1.49	1.99	0.89	3.02	1.48	-0.54	-0.76	-0.42	-0.50
NIA-Amber	2.23	0.92	0.71	0.41	1.06	0.27	-0.88	-0.99	-0.92	-1.00
NIFA-Barsat	-1.40	-0.55	-1.53	-0.71	-1.99	-1.11	1.02	1.08	0.66	0.64
NIA-Saarang	0.90	0.76	1.67	0.88	1.63	0.46	-0.58	-0.80	-0.73	-0.93
Khirman	-0.76	-0.41	-0.87	-0.48	-0.85	-0.21	0.06	0.21	0.42	0.63
SKD-1	-0.14	-0.35	-0.80	-0.41	-0.78	-0.25	0.52	0.59	0.31	0.30
SE	**0.45**	**0.28**	**0.49**	**0.25**	**0.66**	**0.30**	**0.22**	**0.27**	**0.21**	**0.25**

GCA = General Combining Ability, **cm** = Centimeter, **No**. = Number, **SE** = Standard Error and $^{-1}$ = Per (each)

Table 3. The effects of general combining ability (GCA) on the parents of wheat genotypes for number of spikelets spike^{-1}, number of grains spike^{-1}, grain weight spike^{-1}, grain yield plant^{-1} and seed index grown under non-stress and heat stress conditions.

Parents	Number. of spikelets spike^{-1}		No. of grains spike^{-1}	Grain weight spike^{-1}			Grain yield plant^{-1} (g)		Seed index (1000 gr.)	
	Non-stress	Heat stress	Non-stress	Heat stress	Non-stress	Heat stress	Non-stress	Heat stress	Non-stress	Heat stress
TJ-83	0.95	1.23	3.05	4.07	0.29	0.32	0.14	0.30	1.40	1.37
Sehar-2006	-1.63	-1.52	-2.60	-3.12	-0.27	-0.29	-1.21	-1.10	-1.64	-1.50
Sarsabz	0.30	0.61	1.05	2.14	0.29	0.30	1.06	1.09	0.97	1.14
AS-2002	-0.38	-0.91	-1.85	-2.93	-0.32	-0.34	-0.31	-0.47	-1.44	-1.39
NIA-Amber	-0.18	-0.40	-1.81	-3.01	-0.32	-0.34	-0.48	-0.60	-0.97	-1.34
NIFA-Barsat	0.93	0.99	2.15	2.85	0.32	0.35	0.81	0.78	1.68	1.71
NIA-Saarang	-0.91	-1.03	-1.21	-2.45	-0.32	-0.34	-0.73	-0.75	-0.93	-1.08
Khirman	0.11	0.28	0.59	1.21	0.16	0.17	0.17	0.17	0.56	0.51
SKD-1	0.80	0.76	0.61	1.24	0.15	0.17	0.56	0.58	0.37	0.57
SE	**0.29**	**0.33**	**0.65**	**0.96**	**0.10**	**0.10**	**0.25**	**0.25**	**0.42**	**0.44**

GCA = General Combining Ability, **cm** = Centimeter, **No**. = Number, **SE** = Standard Error and $^{-1}$ = Per (each

Table 4. The effects of specific combining ability (SCA) on F_1 hybrids of bead wheat for days to 75% heading, days to 75% maturity, plant height, number of tillers plant^{-1}and spike length spike^{-1} grown under non-heat stress and heat- stress conditions.

F_1 hybrids	Days to 75% heading		Days to 75% maturity		Plant height (cm)		Number of tillers plant^{-1}		Spike length (cm)	
	Non-stress	Heat stress	Non-stress	Heat stress	Non-stress	Heat stress	Non-stress	Heat stress	Non-stress	Heat stress
T.J-83 x NIA-Saarang	1.43	0.50	0.41	-0.06	2.86	1.17	-0.37	-0.66	-0.55	-0.95
T.J-83 x Khirman	-2.54	-1.11	-1.09	-0.74	-2.96	-1.46	1.32	0.91	0.98	1.04
T.J-83 x SKD-1	-1.21	-0.93	-1.07	-0.72	-2.00	-1.02	1.17	0.76	0.84	1.27
Sehar-2006 x NIA-Saarang	-0.45	-0.34	-0.17	0.97	-1.17	-0.29	-1.46	0.02	-0.28	-0.08
Sehar-2006 x Khirman	0.86	0.51	-0.14	-0.13	1.62	1.32	-0.80	-0.28	-0.16	-0.41
Sehar-2006 x SKD-1	0.35	0.14	0.70	0.57	1.35	0.14	0.14	-0.47	-0.27	-0.19
Sarsabz x NIA-Saarang	1.40	-0.04	0.74	0.72	2.12	0.10	0.10	-0.43	-0.97	-1.12
Sarsabz x Khirman	-1.02	-0.65	-0.96	-0.49	-1.91	-0.80	1.14	0.71	0.89	1.08
Sarsabz x SKD-1	-0.74	-0.57	-0.86	-0.45	-1.64	-0.74	1.11	0.59	0.83	0.95
AS-2002 x NIA-Saarang	-0.66	0.62	0.12	0.07	-0.48	0.10	0.10	0.00	-0.01	0.18
AS-2002 x Khirman	0.21	-0.05	0.89	-0.01	1.59	0.19	-0.28	-0.09	0.06	-0.08

AS-2002 x SKD-1	0.64	0.24	0.18	0.38	0.41	0.18	-0.29	-0.49	-0.95	-1.19
NIA-Amber x NIA-Saarang	-0.73	-0.24	-0.24	0.14	-0.73	-0.28	-1.02	0.44	-0.25	-0.01
NIA-Amber x Khirman	1.13	1.35	0.68	0.55	0.54	-0.12	-0.12	-0.79	-0.36	-0.37
NIA-Amber x SKD-1	1.40	0.59	0.34	-0.04	1.37	1.14	-0.37	-0.12	-0.43	-0.71
Nifa Barsat Barsat x NIA Saarang,	1.76	0.69	1.45	-0.11	1.90	1.11	-0.74	-1.16	-0.59	-0.87
Nifa Barsat Barsat x Khirman	-0.98	-0.55	-0.56	-0.40	-1.47	-0.37	0.19	0.64	0.79	0.88
Nifa Barsat Barsat x SKD-1	-0.85	-0.16	-0.41	-0.23	-1.38	-0.37	0.18	0.45	0.43	0.60
SE	**0.28**	**0.15**	**0.17**	**0.11**	**0.41**	**0.19**	**0.13**	**0.14**	**0.15**	**0.19**

SCA = Specific Combining Ability**, cm** = Centimeter, SE = Standard Error, **$^{-1}$** = Per (each) and % = Percentage

Table 5. The effects of Specific Combining Ability (SCA) on F1 hybrids of bread wheat for Number of spikelets spike^{-1}, grain spike^{-1}, grain weight spike^{-1}, and grain yield plant^{-1} and seed index grown under non-heat stress and heat stress conditions.

F_1 hybrids	**Number of spikelets spike^{-1}**		**Number of grains spike^{-1}**		**Grain weight spike^{-1} (g)**		**Grain yield plant^{-1} (g)**		**Seed index (1000gr.)**	
	Non-stress	**Heat stress**	**Non-stress**	**Heat stress**	**Non-stress**	**Heat stress**	**Non-stress**	**Heat stress**	**Non-stress**	**Heat stress**
T.J-83 x NIA-Saarang	-0.79	-0.75	-0.65	-1.70	-0.28	-0.31	-0.83	-0.84	-1.42	-1.47
T.J-83 x Khirman	1.56	1.30	2.25	3.09	0.32	0.34	1.31	1.25	1.52	1.85
T.J-83 x SKD-1	1.07	1.20	2.24	2.37	0.28	0.30	0.88	0.90	1.20	1.46
Sehar-2006 x NIA-Saarang	0.25	0.48	-0.65	0.53	0.14	0.13	0.17	0.31	0.22	0.36
Sehar-2006 x Khirman	-1.00	-0.99	-1.67	-2.07	-0.16	-0.15	-0.18	-0.19	-0.55	-0.49
Sehar-2006 x SKD-1	0.21	0.12	0.46	-0.30	-0.16	-0.19	-1.14	-1.06	-0.97	-1.36
Sarsabz x NIA-Saarang	-1.83	-1.80	-2.35	-2.66	-0.29	-0.29	-0.97	-0.92	-1.67	-1.34
Sarsabz x Khirman	1.02	0.94	2.00	2.29	0.24	0.29	0.72	0.74	1.74	1.11
Sarsabz x SKD-1	0.80	0.87	1.23	2.29	0.16	0.18	0.66	0.54	1.14	1.09
AS-2002 x NIA-Saarang	0.28	0.31	0.22	1.10	0.14	0.14	0.25	0.18	0.53	0.51
AS-2002 x Khirman	-0.38	-0.23	-0.56	-1.49	-0.13	-0.15	-0.05	-0.12	0.05	-0.51
AS-2002 x SKD-1	-1.17	-1.07	-1.69	-1.60	-0.11	-0.14	-0.47	-0.41	-0.79	-0.58
NIA-Amber x NIA-Saarang	0.50	0.26	1.11	1.13	0.13	0.15	0.41	0.41	0.35	0.94
NIA-Amber x Khirman	-0.48	-0.29	-0.60	-0.38	-0.13	-0.15	-0.69	-0.68	-0.60	-0.81
NIA-Amber x SKD-1	-0.55	-0.90	-1.41	-1.91	-0.15	-0.15	-0.19	-0.21	-1.14	-0.65
Nifa Barsat Barsat x NIA Saarang,	-0.77	-0.86	-2.46	-3.39	-0.27	-0.32	-0.91	-0.93	-0.91	-1.59
Nifa Barsat Barsat x Khirman	0.75	0.86	1.31	1.53	0.14	0.17	0.52	0.54	0.74	0.83
Nifa Barsat Barsat x SKD-1	0.51	0.53	1.22	1.17	0.14	0.15	0.50	0.52	0.56	0.65
SE	**0.21**	**0.21**	**0.37**	**0.47**	**0.05**	**0.05**	**0.17**	**0.17**	**0.25**	**0.26**

SCA = Specific Combining Ability, **cm** = Centimeter, SE = Standard Error, **$^{-1}$** = Per (each) and **% =** Percentage

Conclusions

Keeping in view the overall results of the present investigation regarding yield, morphological and physiological characters of the parents and F_1 hybrids shown by lines x tester mating design under terminal heat stress are concluded. The morphological and yield haracters were significantly affected by the terminal heat stress and the importance of treatment x parent relations exhibited that parents performed inconsistency through-out non-heat stress condition, however some were observed more heat stress tolerant than the other. The bread wheat parental lines , T.J-83, NIFA- Barsat and Sarsabaz performed very well under heat stress condition for almost all the yield and morphological parameters while the second heat stress tolerant category parents were SKD-1 and Khirman. The Combining Ability (GCA) and Specific Combinng Ability (SCA) were significantly higher for almost yield and morphological. Hence, under both non-heat stress and heat stress conditions revealed that T.J.-83, NIFA-Barsat, Sarsabaz, SKD-1, and Khirman were identified as good common combiners; as a result, these parents could be used in the future for selection and hybridization programmes under terminal heat stress tolerance. Among the eighteen F_1 hybrids examined, the crosses, T.J-83 x NIFA-Barsat, T.J-83 x SKD-1, Sarsabaz x Khirman, Nifa Barsat Barsat x SKD-1, Sarsabaz x SKD-1 and NIFA x Khirman acknowledged to be good specific combiners for majority of the yield and morphological characters, therefore these hybrids should be considered as potential F1 hybrids for crossbreed in terminal heat stress condition.

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