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*RESEARCH PAPER*

# Identification of stress indices for screening of rice cultivars under high temperature

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**Abstract :** Rice is an important cereal crop and its productivity is being affected by many abiotic and biotic stresses. High temperature affects the rice yield and productivity. Thirty rice genotypes were evaluated in normal and under high temperature stress conditions. There was reduction in grain yield in all the tested genotypes. Based on yield recorded under normal and high temperature conditions, yield based indices were calculated. Stress Susceptibility Index (SSI), Geometric Mean Production (GMP), Mean Production (MP), Yield Index (YI), Modified stress tolerance (K1STI and K2STI) were significantly and positively correlated to yield under both stress and non-stress conditions and could be considered as good selection indices for screening for heat tolerance. Genotypes were ranked based on their tolerant or susceptibility indices and it was noted that among all IET 28412, IET 28397 and IET 28432 exhibited highest mean rank and a lower standard deviation of rank, hence they can be identified as heat tolerant genotypes. Genotypes IET 26468, IET 28393 and Gontrabidhan-3 were identified as highly susceptible to high temperature stress.

**Key Words :** Rice, Correlation, High temperature, Stress index, Yield

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## INTRODUCTION

Rice is staple food crop for more than 50% of the global population. Among abiotic stresses that hamper rice production and productivity, it is the episodes of high temperature that affect it the most. Keeping the climate change in view, global warming is now a major concern and as a result heat waves would be more frequent and is a threat for crop production (Xu *et al*., 2018; Janni *et al.,* 2020). It has been estimated that the mean temperatures are expected to increase by 2-3°C in the coming 30–50 years (Hatfield and Prueger, 2015) and this is certainly a concern for the farming community.

High temperature affects physiological mechanisms by hampering the photosynthesis related activities, stomatal movements, growth, yield and quality of rice crop (Kilasi *et al*., 2018). Of all the growth stages, flowering and booting stages are the most sensitive stage of the crop when exposed to high temperature (Pradhan *et al*., 2016). Increased temperature if coincides during the post anthesis stage of rice, especially during grain development terminates grain growth prematurely and reduces yield considerably.

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Peng *et al*. (2004) stated that increase in average temperature by 1°C reduced the grain yield in rice by 10%. Loss of yield is a concern to the rice scientists and farmers and hence there is a need to identify and develop high temperature tolerant cultivars to meet the demand for food in future climates (Naghavi *et al*., 2013). The ability of any crop to yield substantially under stressed environment is paramount for stability of production. The relative yield performance of the tested genotypes when grown under stress and ambient conditions could be used as an indicator to identify tolerant varieties in breeding for high temperature stress.

Yield based indices could be used as a tool for evaluation of any stress tolerant genotypes and in the present experiment yield based indices were computed for the identification of high temperature tolerant genotypes. Heat indices which provide a measure of loss of yield under high temperature conditions in comparison to normal can be used for screening heat tolerant genotypes as done in case of drought stress by Mitra, (2001). These yield-based indices could also be used for the evaluation of high temperature tolerance for applied plant breeding programmes (Porch, 2006). Thus, with this objective thirty rice cultivars were screened for high temperature tolerance to identify suitable yield indices that could be used as screening parameter and also to identify high temperature tolerant rice genotypes.

## MATERIAL AND METHODS

**Plant material:**

A field experiment was carried out in *Kharif* 2019 at Regional Agricultural Research Station, Maruteru with thirty rice genotypes. The experiment was laid out in split plot with spacing of 20x15 cm. Recommended dose of Nitrogen (N), Phosphorus (P) and Potassium (K) (100:60:60 kg/ha) was applied. All package of practices recommended for irrigated transplanted rice were followed.

One set of genotype was grown in ambient conditions and another set was subjected to high temperature stress by enclosing a polythene sheet supported by bamboo poles and iron frame at panicle initiation (PI) stage. Temperature inside the polyhouse was monitored continuously upto physiological maturity. The mean maximum temperature in the ambient condition was 31.5°C and the average mean minimum temperature was 22.2°C. Whereas, under polyhouse the mean monthly maximum temperature was 35.9°C and the average of monthly minimum temperature was 24.8°C. The difference in mean monthly maximum and minimum temperature was 4.4°C and 2.6°C, respectively.

At physiological maturity, panicles from each genotype in both normal and high temperature condition from demarcated area of one meter square was collected, dried, threshed, cleaned and the weight of grains was recorded and expressed in g $m^{-2}$.

**Yield based indices:**

Based on the grain yield under control (Yp) and grain yield under stress (Ys) heat tolerant indices were computed namely, Stress Susceptibility Index (SSI), Relative Heat Index (RHI), Stress tolerance index (STI), Geometric Mean Production (GMP), Mean Production (MP), Yield Index (YI), Heat resistance index (HI), Yield Stability Index (YSI), Stress Susceptibility Percentage Index (SSPI) and Modified stress tolerance (K1STI and K2STI) (Moosavi *et al*., 2008; Farshadfar and Sutka, 2002). Correlation between grain yield under normal and stress conditions with the above calculated yield based indices was done in MS Excel so as to identify suitable screening index.

After computing the indices, the tested genotypes were ranked according to each index in such a way that a good performing genotype was given the highest rank. Mean rank and standard deviation for the ranks were calculated.

**Statistical analysis:**

Two way analysis of variance (ANOVA) was performed using an open source software R (R Core Team, 2012) with Agricolae package (de Mendiburu, 2012). Statistical significance of the parameter means was determined by performing Fisher's LSD test to test the statistical significance.

## RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

**Grain yield (g $m^{-2}$) :**

Exposure to high temperature led to reduction in grain yield by 13.6%. Grain yield was higher in IET 28400 (530 g $m^{-2}$) followed by IET 28386 (507 g $m^{-2}$), IET 28397 (495 g $m^{-2}$) and IET 28387 (493 g $m^{-2}$) whereas lower in IET 26468 (270 g $m^{-2}$), IET 28393 (279 g $m^{-2}$),

Gontrabidhan-3 (326 g $m^{-2}$) and IET 28409 (341 g $m^{-2}$) under high temperature stress. Lesser reduction in grain yield was evident in IET 28407 (5.6%), IET 28411 (6.3%), IET 28412 (6.5%) and IET 28384 (6.8%). On the contrary, higher was in IET 28409 (35.1%), IET 26468 (29.1%) and IET 28393 (24.1%). (Fig.1). Rice plants are susceptible to high temperature stress during the reproductive stage. Results revealed reduction in the grain yield of all the tested genotypes. The underlying cause may be mostly the effect of high temperature on phenological development processes in plant that led to reduction in grain yields (Giaveno and Ferrero, 2003). Shi *et al*. (2015) also reported that heat stress at reproductive stage had shown impact on grain yield and its component traits in rice.

**Performance of cultivars based on the resistance/ tolerance indices:**

*Stress susceptibility index* (SSI):

SSI indicates the susceptible level of an entry. It varied from 2.59 (IET 28409) to 0.41 (IET 28407). Higher SSI was noted in IET 28409 (2.59), IET 26468 (2.14) and IET 28393 (1.77) and lower SSI was noted in IET 28407 (0.41), IET 28411 (0.46) and IET 28412 (0.47) (Table 1).

*Relative heat index* (RHI):

Lower RHI was observed in IET 28409 (0.75), IET 26468 (0.82) and IET 28393 (0.88) whereas higher RHI was in IET 28407 (1.09), IET 28411 (1.08), IET 28412 (1.08), IET 28384 (1.08) and IET 28408 (1.08).

*Stress tolerance index* (STI):

STI was maximum in IET 28400 (1.51), IET 28386 (1.41), IET 28387 (1.24) and IET 28397 (1.20). Minimum STI was recorded in IET 28393 (0.46), IET 26468 (0.46), Gontrabidhan-3 (0.58), IET 28423 (0.62) and IET 28411 (0.62) (Table 1).

***Geometric mean production* (GMP):**

GMP ranged from 582 (IET 28400) to 320 (IET 28393 and IET 26468). It was highest in IET 28400, IET 28386, IET 28387, and IET 28397. Lowest was in IET 28393, IET 26468, Gontrabidhan-3 and IET 28423.

***Mean production* (MP):**

Maximum MP was recorded in IET 28400 (585), IET 28386 (564), IET 28387 (528) and IET 28397 (519). Minimum MP was in IET 28393 (323), IET 26468 (325), Gontrabidhan-3 (362) and IET 28411 (371) (Table 1).

***Yield index* (YI):**

YI ranged from 1.30 (IET 28400) to 0.66 (IET 26468). High YI was noted in IET 28400 (1.30), IET 28386 (1.24), IET 28397 and IET 28387 (1.21). However YI was low in IET 26468 (0.66), IET 28393 (0.68),

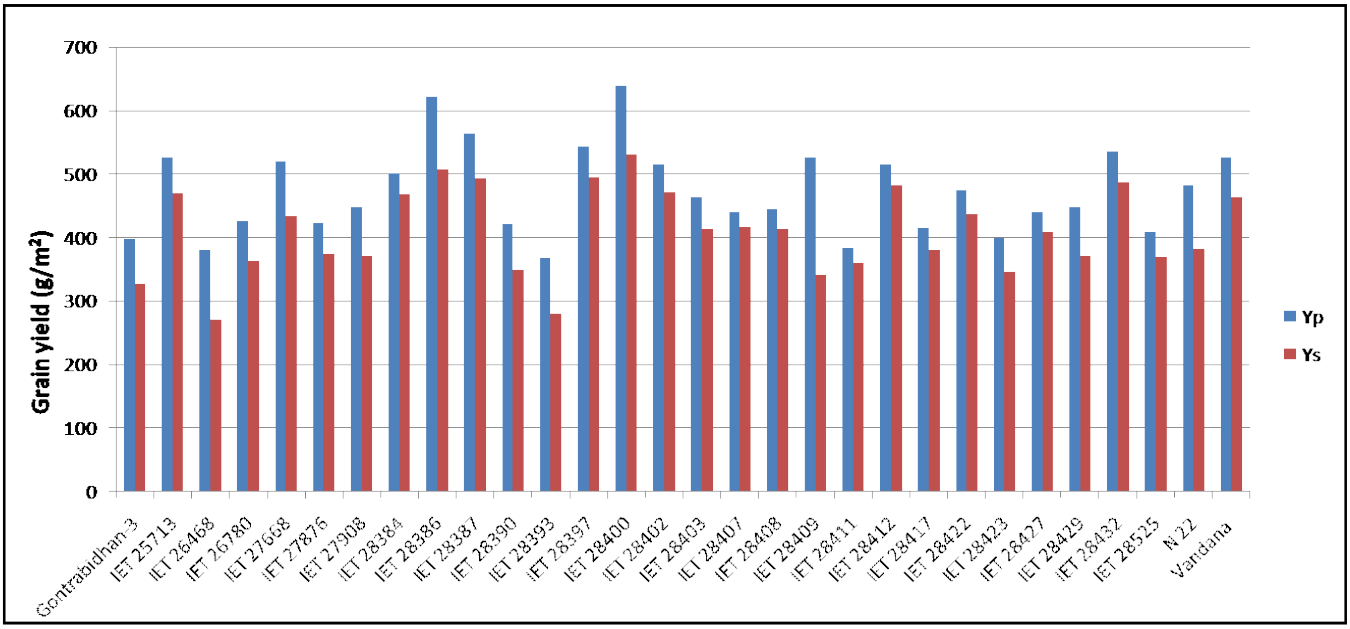


**Fig. 1: Effect of high temperature on grain yield (g $m^{-2}$) of rice genotypes Yp- Yield under control, Ys- Yield under high temperature (stress)**

Gontrabidhan-3 (0.80) and IET 28409 (0.83).

***Heat resistance index* (HI):**

HI ranged from 1.10 (IET 28397 and IET 28412) to 0.47 (IET 26468). Maximum HI was observed in IET 28397 and IET 28412 (1.10) closely followed by IET 28432 (1.09) and IET 28400 (1.08). Minimum HI was in IET 26468 (0.47) and IET 28393 (0.52).

***Yield stability index* (YSI):**

Higher values for YSI were observed in IET 28407, IET 28411 and IET 28412 (0.94). Lowest YSI was recorded in IET 28409 (0.65) (Table 1).

***Modified stress tolerance* (K1STI and K2STI)**:

IET 28400, IET 28386, IET 28387, IET 28397 and IET 28432 recorded highest K1STI. IET 28393, IET 26468, IET 28411 and Gontrabidhan-3 recorded lowest. K2STI was highest in IET 28400, IET 28386, IET 28397 and IET 28387, lowest in IET 26468, IET 28393 and Gontrabidhan-3.

**Table 1 : Tolerant and susceptibility indices of rice genotypes under high temperature conditions**

| Entry | SSI | RHI | STI | GMP | MP | YI | HI | YSI | K1 | K2 | SSPI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gontrabidhan-3 | 1.32 | 0.95 | 0.58 | 360 | 362 | 0.80 | 0.66 | 0.82 | 0.71 | 0.64 | 7.54 |
| IET 25713 | 0.78 | 1.03 | 1.11 | 497 | 498 | 1.15 | 1.03 | 0.89 | 1.24 | 1.32 | 5.92 |
| IET 26468 | 2.14 | 0.82 | 0.46 | 320 | 325 | 0.66 | 0.47 | 0.71 | 0.65 | 0.44 | 11.70 |
| IET 26780 | 1.08 | 0.99 | 0.69 | 393 | 394 | 0.89 | 0.76 | 0.85 | 0.81 | 0.79 | 6.66 |
| IET 27668 | 1.21 | 0.97 | 1.01 | 474 | 476 | 1.06 | 0.89 | 0.83 | 1.21 | 1.13 | 9.09 |
| IET 27876 | 0.85 | 1.02 | 0.70 | 397 | 398 | 0.91 | 0.81 | 0.88 | 0.80 | 0.83 | 5.22 |
| IET 27908 | 1.27 | 0.96 | 0.74 | 407 | 409 | 0.91 | 0.75 | 0.83 | 0.90 | 0.82 | 8.18 |
| IET 28384 | 0.50 | 1.08 | 1.05 | 484 | 484 | 1.14 | 1.07 | 0.93 | 1.12 | 1.31 | 3.63 |
| IET 28386 | 1.35 | 0.94 | 1.41 | 561 | 564 | 1.24 | 1.01 | 0.82 | 1.73 | 1.54 | 12.09 |
| IET 28387 | 0.89 | 1.02 | 1.24 | 527 | 528 | 1.21 | 1.06 | 0.88 | 1.43 | 1.46 | 7.54 |
| IET 28390 | 1.26 | 0.96 | 0.65 | 382 | 385 | 0.85 | 0.71 | 0.83 | 0.80 | 0.73 | 7.75 |
| IET 28393 | 1.77 | 0.88 | 0.46 | 320 | 323 | 0.68 | 0.52 | 0.76 | 0.60 | 0.47 | 9.34 |
| IET 28397 | 0.65 | 1.06 | 1.20 | 518 | 519 | 1.21 | 1.10 | 0.91 | 1.32 | 1.47 | 5.15 |
| IET 28400 | 1.25 | 0.96 | 1.51 | 582 | 585 | 1.30 | 1.08 | 0.83 | 1.83 | 1.68 | 11.53 |
| IET 28402 | 0.59 | 1.06 | 1.08 | 491 | 493 | 1.15 | 1.07 | 0.92 | 1.19 | 1.33 | 4.69 |
| IET 28403 | 0.79 | 1.03 | 0.85 | 437 | 438 | 1.01 | 0.90 | 0.89 | 0.96 | 1.02 | 5.36 |
| IET 28407 | 0.41 | 1.09 | 0.82 | 427 | 428 | 1.02 | 0.96 | 0.94 | 0.87 | 1.03 | 2.61 |
| IET 28408 | 0.51 | 1.08 | 0.82 | 428 | 429 | 1.01 | 0.94 | 0.93 | 0.88 | 1.02 | 3.28 |
| IET 28409 | 2.59 | 0.75 | 0.80 | 423 | 433 | 0.83 | 0.54 | 0.65 | 1.24 | 0.70 | 19.53 |
| IET 28411 | 0.46 | 1.08 | 0.62 | 371 | 371 | 0.88 | 0.83 | 0.94 | 0.66 | 0.78 | 2.54 |
| IET 28412 | 0.47 | 1.08 | 1.11 | 498 | 498 | 1.18 | 1.10 | 0.94 | 1.19 | 1.39 | 3.52 |
| IET 28417 | 0.61 | 1.06 | 0.71 | 397 | 398 | 0.93 | 0.85 | 0.92 | 0.77 | 0.87 | 3.67 |
| IET 28422 | 0.59 | 1.06 | 0.92 | 455 | 455 | 1.07 | 0.98 | 0.92 | 1.01 | 1.14 | 4.09 |
| IET 28423 | 0.95 | 1.01 | 0.62 | 371 | 372 | 0.85 | 0.74 | 0.87 | 0.71 | 0.72 | 5.50 |
| IET 28427 | 0.52 | 1.07 | 0.80 | 423 | 423 | 1.00 | 0.93 | 0.93 | 0.86 | 1.00 | 3.31 |
| IET 28429 | 1.27 | 0.96 | 0.74 | 407 | 409 | 0.91 | 0.75 | 0.83 | 0.90 | 0.82 | 8.18 |
| IET 28432 | 0.66 | 1.05 | 1.16 | 510 | 511 | 1.19 | 1.09 | 0.91 | 1.28 | 1.42 | 5.11 |
| IET 28525 | 0.72 | 1.04 | 0.67 | 388 | 388 | 0.90 | 0.81 | 0.90 | 0.75 | 0.81 | 4.23 |
| N 22 | 1.53 | 0.92 | 0.82 | 428 | 431 | 0.93 | 0.74 | 0.79 | 1.04 | 0.87 | 10.57 |
| Vandana | 0.86 | 1.02 | 1.09 | 494 | 495 | 1.14 | 1.00 | 0.88 | 1.24 | 1.29 | 6.56 |
| Mean | 1.00 | 1.00 | 0.88 | 439 | 440 | 1.00 | 0.87 | 0.86 | 1.02 | 1.03 | 6.80 |
| LSD (G) P<0.05) | 0.62 | 0.09 | 0.10 | 25.3 | 25.07 | 0.07 | 0.14 | 0.08 | 0.15 | 0.16 | 4.44 |

***Stress susceptibility percentage index* (SSPI):**

Maximum values for SSPI was in IET 28409 (19.53), IET 28386 (12.09), IET 26468 (11.70) and IET 28400 (11.53). However, minimum values were in IET 28411 (2.54), IET 28407 (2.61), IET 28408 (3.28) and IET 28427 (3.31) (Table 1).

**Correlation analysis:**

Correlation analysis between Ys, Yp and other tolerance and susceptibility indices revealed a negative correlation between Ys and SSI and Ys and SSPI however it was non-significant between Ys and SSPI and significant between Ys and SSI. The remaining indices *viz.,* RHI, STI, GMP, MP, YI, HI, YSI, K1 ST1 and K2 STI were positively and significantly correlated with Ys. STI, GMP, MP, YI, HI, K1 and K2 were significantly and positively correlated to yield under both stress and non-stress conditions and could be considered as good selection indices (Table 2).

Performance of a genotype in terms of yield is of importance in rice breeding programmes. Computing yield based indices can be essential in identifying tolerant genotypes. It is an effective tool for screening for abiotic stresses like drought, salinity and high temperature. A lot of work on computing indices under drought has been done, reports on indices under high temperature are few.

In the present study there was a positive and significant correlation between GMP, STI and MP both with Yp and Ys. In a study conducted on wheat it has been reported that genotypes with high GMP and STI and less SSI are tolerant (Mohammadi *et al*., 2008). STI as a very reliable indicator for selection of suitable cultivars in both stress and non-stress conditions was reported by Nouraein *et al*., (2013). MP, GMP, and STI are the best indexes to evaluate genotypes tolerance in wheat was reported by Mohammadijoo *et al*., (2015). YI is an important selection parameter for drought tolerance in rice (Khan and Dhurve, 2016). In our study too YI had a positive correlation with yield under stress condition.

It has been also stated that the indices having a high correlation with yield under normal and stress can be considered as best indices for screening germplasm (Naghavi *et al*., 2013). So in this study the indices STI, GMP, MP, HI, YI, K1 and K2 can be identified as best indices for screening large germplasm in high temperature stress studies.

**Ranking method:**

The genotypes IET 28412, IET 28397 and IET 28432 exhibited the highest mean rank and a lower standard deviation of rank (SDR), hence they can be identified as heat tolerant genotypes. Genotypes IET 26468, IET 28393 and Gontrabidhan-3 as susceptible to high temperature stress (Table 3).

Ranking method for identification of tolerant corn cultivars was followed by Naghavi *et al*. (2013) based on drought indices computed and correlated with Ys and

**Table 2 : Correlation co-efficient between Yp, Ys and tolerance or susceptibility indices in rice genotypes**

| | Yp | Ys | SSI | RHI | STI | GMP | MP | YI | HI | YSI | K1 | K2 | SSPI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yp | 1 | | | | | | | | | | | | |
| Ys | 0.872*** | 1*** | | | | | | | | | | | |
| SSI | -0.025 | -0.506** | 1 | | | | | | | | | | |
| RHI | 0.025 | 0.506** | -1.000 | 1 | | | | | | | | | |
| STI | 0.967*** | 0.962*** | -0.259 | 0.259 | 1 | | | | | | | | |
| GMP | 0.961*** | 0.973*** | -0.297 | 0.297 | 0.996 | 1 | | | | | | | |
| MP | 0.968*** | 0.967*** | -0.271 | 0.271 | 0.997 | 1.000 | 1 | | | | | | |
| YI | 0.872*** | 1*** | -0.506 | 0.506 | 0.962 | 0.973 | 0.967 | 1 | | | | | |
| HI | 0.68*** | 0.951*** | -0.744 | 0.744 | 0.833 | 0.855 | 0.841 | 0.951 | 1 | | | | |
| YSI | 0.025 | 0.506** | -1.000 | 1.000 | 0.259 | 0.297 | 0.271 | 0.506 | 0.744 | 1 | | | |
| K1 | 0.997*** | 0.857*** | 0.000 | 0.000 | 0.964 | 0.951 | 0.959 | 0.857 | 0.658 | 0.000 | 1 | | |
| K2 | 0.89*** | 0.996*** | -0.461 | 0.461 | 0.975 | 0.979 | 0.974 | 0.996 | 0.934 | 0.461 | 0.880 | 1 | |
| SSPI | 0.302 | -0.202 | 0.937 | -0.937 | 0.062 | 0.028 | 0.055 | -0.202 | -0.492 | -0.937 | 0.325 | -0.160 | 1 |

(n-2)= 28, * =(p<0.05), ** = (p<0.01), *** = (p<0.001)

Yp. On similar lines, in the present study too the tested genotypes were ranked according to their computed indices and the genotypes having the highest mean rank and a lower standard deviation of rank, were identified as heat tolerant genotypes. Based on this, among the genotypes tested IET 28412, IET 28397 and IET 28432 were identified as heat tolerant genotypes. Multilocation trials conducted under ICAR- AICRIP (All India Coordinated Rice Improvement Project) on screening for high temperature tolerance showed strong association between yield based indices with both Yp and Ys. Most of the tolerance indices showed strong positive association and the susceptibility indices showed a strong negative association. Indices GMP, K2STI and YI showed highly significant positive association with Ys and these indices were useful in selecting genotypes for heat tolerance (IIRR Annual Progress Report, 2020).

## Conclusion:

In this study, out of the computed 11 indices STI, GMP, MP, YI, K1STI, K2STI were selected as most effective and suitable stress indices for identifying tolerant rice genotypes with high yield potential under high temperature conditions as correlation analysis

**Table 3: Rank, rank mean and standard deviation of ranks (SDR) of heat tolerance or susceptibility indices in rice genotypes**

| Entry | SSI | RHI | STI | GMP | MP | YI | HI | YSI | K1 | K2 | SSPI | Mean | SDR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gontrabidhan-3 | 6 | 6 | 3 | 3 | 3 | 3 | 4 | 6 | 4 | 3 | 12 | 5 | 2.6 |
| IET 25713 | 18 | 18 | 24 | 24 | 24 | 23 | 23 | 18 | 24 | 23 | 15 | 21 | 3.2 |
| IET 26468 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | 2 | 0.6 |
| IET 26780 | 12 | 12 | 8 | 8 | 8 | 8 | 10 | 12 | 10 | 8 | 13 | 10 | 1.9 |
| IET 27668 | 11 | 11 | 20 | 20 | 20 | 19 | 15 | 11 | 22 | 19 | 7 | 16 | 4.9 |
| IET 27876 | 16 | 16 | 9 | 9 | 10 | 12 | 11 | 16 | 9 | 12 | 18 | 13 | 3.2 |
| IET 27908 | 8 | 8 | 12 | 12 | 12 | 11 | 9 | 8 | 15 | 11 | 9 | 10 | 2.1 |
| IET 28384 | 27 | 27 | 21 | 21 | 21 | 22 | 26 | 27 | 19 | 22 | 25 | 23 | 2.8 |
| IET 28386 | 5 | 5 | 29 | 29 | 29 | 29 | 22 | 5 | 29 | 29 | 2 | 19 | 11.6 |
| IET 28387 | 14 | 14 | 28 | 28 | 28 | 27 | 24 | 14 | 28 | 27 | 11 | 22 | 6.8 |
| IET 28390 | 9 | 9 | 6 | 6 | 6 | 6 | 5 | 9 | 8 | 6 | 10 | 7 | 1.7 |
| IET 28393 | 3 | 3 | 1 | 1 | 1 | 2 | 2 | 3 | 1 | 2 | 6 | 2 | 1.4 |
| IET 28397 | 21 | 21 | 27 | 27 | 27 | 28 | 30 | 21 | 27 | 28 | 19 | 25 | 3.6 |
| IET 28400 | 10 | 10 | 30 | 30 | 30 | 30 | 27 | 10 | 30 | 30 | 4 | 22 | 10.3 |
| IET 28402 | 24 | 24 | 22 | 22 | 22 | 24 | 25 | 24 | 21 | 24 | 21 | 23 | 1.3 |
| IET 28403 | 17 | 17 | 18 | 18 | 18 | 16 | 16 | 17 | 16 | 16 | 17 | 17 | 0.8 |
| IET 28407 | 30 | 30 | 15 | 15 | 14 | 18 | 19 | 30 | 12 | 18 | 29 | 21 | 6.9 |
| IET 28408 | 26 | 26 | 16 | 16 | 15 | 17 | 18 | 26 | 13 | 17 | 28 | 20 | 5.2 |
| IET 28409 | 1 | 1 | 14 | 14 | 17 | 4 | 3 | 1 | 23 | 4 | 1 | 8 | 7.6 |
| IET 28411 | 29 | 29 | 5 | 5 | 4 | 7 | 13 | 29 | 3 | 7 | 30 | 15 | 11.3 |
| IET 28412 | 28 | 28 | 25 | 25 | 25 | 25 | 29 | 28 | 20 | 25 | 26 | 26 | 2.4 |
| IET 28417 | 22 | 22 | 10 | 10 | 9 | 13 | 14 | 22 | 7 | 13 | 24 | 15 | 5.9 |
| IET 28422 | 23 | 23 | 19 | 19 | 19 | 20 | 20 | 23 | 17 | 20 | 23 | 21 | 2.0 |
| IET 28423 | 13 | 13 | 4 | 4 | 5 | 5 | 6 | 13 | 5 | 5 | 16 | 8 | 4.4 |
| IET 28427 | 25 | 25 | 13 | 13 | 13 | 15 | 17 | 25 | 11 | 15 | 27 | 18 | 5.8 |
| IET 28429 | 7 | 7 | 11 | 11 | 11 | 10 | 8 | 7 | 14 | 10 | 8 | 9 | 2.1 |
| IET 28432 | 20 | 20 | 26 | 26 | 26 | 26 | 28 | 20 | 26 | 26 | 20 | 24 | 3.1 |
| IET 28525 | 19 | 19 | 7 | 7 | 7 | 9 | 12 | 19 | 6 | 9 | 22 | 12 | 5.8 |
| N 22 | 4 | 4 | 17 | 17 | 16 | 14 | 7 | 4 | 18 | 14 | 5 | 11 | 5.7 |
| Vandana | 15 | 15 | 23 | 23 | 23 | 21 | 21 | 15 | 25 | 21 | 14 | 20 | 3.9 |

revealed that these indices were significantly correlated under both Ys and Yp. When a large germplasm is available computing these yield based indices would help in preliminary screening for high temperature tolerant genotypes.

## REFERENCES

**deMendiburu, F. (2012).** *Agricolae: Statistical Procedures for Agricultural Research*. – R package version 1.1-2. *http:// CRAN. Rproject.org/package = agricolae.*

**Farshadfar, E. and Sutka, J. (2002).** Multivariate analysis of drought tolerance in wheat substitution lines. *Cereal Research Communications*, **31**(1/2): 33-39.

**Giaveno, C. and Ferrero, J. (2003).** Introduction of tropical maize genotypes to increase silage production in the central area of Santa Fe, Argentina. *Crop Breeding and Applied Biotechnology*, **3** : 89-94.

**Hatfield, J.L. and Prueger, J.H. (2015).** Temperature extremes: effect on plant growth and development. *Weather Clim. Extrem*, **10**: 4–10.

Indian Institute of Rice Research (IIRR) Annual Progress Report. (2020). Vol. **3** – *Plant Physiology.* Hyderabad. India.

**Janni, M., Gulli, M., Maestri, E., Marmiroli, M., Valliyodan, B., Nguyen, H.T., Marmiroli, N. and Foyer, C. (2020).** Molecular and genetic bases of heat stress responses in crop plants and breeding for increased resilience and productivity. *J. Exp. Bot.*, **71** : 3780-3802.

**Khan, I. and Dhurve, O.P. (2016).** Drought response indices for identification of drought tolerant genotypes in rainfed upland (*Oryza sativa* L). *International Journal of Science, Environment and Tehnology*, **5**(1): 73-83.

**Kilasi, N.L., Singh, J., Vallejos, C.E., Ye, C., Jagadish, S.V.K., Kusolwa, P. and Rathinasabapathi, B. (2018).** Heat Stress Tolerance in Rice (*Oryza sativa* L.): Identification of Quantitative Trait Loci and Candidate Genes for Seedling Growth Under Heat Stress. *Front. Plant Sci.*, **9**:1578.

**Mitra, J. (2001).** Genetics and genetic improvement of drought resistance in crop plants. *Current Science*, **80**(6): 758-762.

**Mohammadi, A., Bihamta, M., Soloki, R. and Roodaki, H.R. (2008).** The study of qualitative and quantitative traits of navy bean and their relation with yield in suitable and limited irrigation conditions. *Journal of Agriculture Sciences*, **1**: 231-243.

**Mohammadijoo, S., Mirasi, A., Saeidi-aboeshaghi, R. and Amiri, M. (2015).** Evaluation of bread wheat (*Triticum aestivum* L.) genotypes based on resistance indices under field conditions. *International Journal of Biosciences*, **6**: 331-337.

**Moosavi, S.S., Yazdi Samadi, B., Naghavi, M.R., Zali, A.A., Dashti, H. and Pourshahbazi, A. (2008).** Introduction of new indices to identify relative drought tolerance and resistance in wheat genotypes. *Desert*, **12**: 165-178.

**Naghavi, M.R., Alireza, P.A. and Marouf, K. (2013).** Evaluation of drought tolerance indices for screening some of corn (*Zea mays* L.) cultivars under environmental conditions. *Notulae Scientia Biologicae*, **5**(3): 388-393.

**Nouraein, M., Mohammadi, S.A., Aharizad, S, Moghaddam, M. and Sadeghzadeh, B. (2013).** Evaluation of drought tolerance indices in wheat recombinant inbred line population. *Annals of Biological Research*, **4**(3): 113-122.

**Peng, S., Huang, J., Sheeshy, J.E., Laza, R.C., Visperas, R.M. (2004).** Rice yields decline with higher night temperature from global warming. *Proceedings of the National Academy of Sciences*, **101**(27): 9971-9975.

**Porch, T.G. (2006).** Application of stress indices for heat tolerance screening of Common Bean. *Journal of Agronomy and Crop Science*, **192**(5): 390-394.

**Pradhan, S.K., Barik, S.R., Sahoo, A., Mohapatra, S., Nayak, D.K., Mahender, A., Meher, J., Anandan, A. and Pandit, E. (2016).** Population structure, genetic diversity and molecular marker trait association analysis for high temperature stress tolerance in rice. *PLoS One*, **11**(8): e0160027.

**R. Core Team (2012).** R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.ISBN 3-900051-07-0, *http://www.R-project.org.*

**Shi, W., Ishimaru, T., Gannaban, R.B., Oane, W. and Jagadish, S.V.K. (2015).** Popular rice (*Oryza sativa* L.) cultivars show contrasting responses to heat stress at gametogenesis and anthesis. *Crop Sci,* **55** : 589–596.

**Xu, Y., Ramanathan, V. and Victor, D.G. (2018).** Global warming will happen faster than we think. *Nature*, **564**: 30-32.