**International Journal of Agriculture, Environment & Biotechnology**
Citation: IJAEB: 7(2): 225-232 June 2014
DOI: 10.5958/2230-732X.2014.00238.1


**Plant Physiology**

# Influence of Priming Treatments on Stress Tolerance During Seed Germination of Rice

**Lakshmi Prasanna Kata[1], M. Bhaskaran[1] and Umarani, R[2]**

[1]Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu -641003, INDIA
[2]Department of Seed Science and Technology, FC&RI, Mettupalayam,Tamil Nadu, INDIA

**Email:** lprasanna.agrico@gmail.com

Paper No. 202 Received: January 28, 2014 Accepted: April 07, 2014 Published: May 26, 2014

**Abstract**

In many crop species, seed germination and early seedling growth are the most sensitive stages to any stress. In order to evaluate the effect of different seed priming techniques on germination of paddy under different temperatures a factorial experiment was conducted with six varieties. Seeds were primed for 12h in seven priming media (salicylic acid 50 ppm, ascorbic acid 200ppm, citric acid 200ppm, proline 0.2%, calcium chloride 2%, $Na_2HPO_4$ 100ppm and distilled water) at three different temperatures ($30^0$C, $38^0$C and $43^0$C) to observe the germination and related parameters. Results indicated that an increase in heat stress decreased germination components such as germination percentage, speed of germination, root length, shoot length and vigour index. Ascorbic acid and salicylic acid pre-treatment @ 200ppm and 50ppm respectively results in improvement of germination properties of paddy under heat stress condition because of its antioxidant capacity. The other treatments also enhanced the germination properties. Priming treatments including hydropriming resulted in the increased activity of α-amylase which in turn has resulted in better mobilization of stored carbohydrate reserves resulted in improvement of germination and other related parameters.

## Highlights

- Ascorbic acid and salicylic acid priming improves germination under high temperature.
- α-amylase is the main enzyme responsible for increased speed of germination in primed seed

**Keywords:** Paddy, temperature, stress, priming, ascorbic acid, salicylic acid

A seed sown to germinate may be exposed to varying environmental conditions in the seedbed before it emerges above the soil surface. These may include high temperatures within the supra-optimal range. The timing of environmental stresses, and not just their intensity, may play a major role in outlining the crop's subsequent emergence pattern (Ferrari, L. and Lopez, C., 2000; Castellani and Aguiar, 2001). Germination is a critical phase in plant life cycle and heat tolerance in germination phase may be important for successful establishment for plants growing in this environment because seed germination is highly dependent on temperature as temperature is one of the basic requisites of this process.

Seed priming has been found a double technology to enhance rapid and uniform emergence, and to achieve high vigour and better yields in some field crops (Murungu *et al.*, 2004; Basra *et al.*, 2005; 2006; Kaur *et al.*, 2005; Farooq *et al.*, 2006 b; 2007 b). As the temperature increases above 30° C, the increase in heat will prevent some seed from sprouting. As the temperature gets higher, more and more seed refuse to germinate. In effect, it is too hot and those seed will not sprout unless the temperature drops. More recently infusion of fungicides, growth regulators, pesticides, bio-products, bio-ingredients, agro-chemicals and herbicides into the seeds prior to germination is reported to alleviate the impact of adverse factors on seed quality and performance (Janmohammadi *et al*, 2008). Application of pre-treatments such as salicylic acid and ascorbic acid in addition to hydropriming of seeds may enhance germination under stress by neutralizing the excessive super oxide radical or singlet oxygen (Tavili *et al*., 2009).

Salicylic acid (SA), an endogenous growth regulator of phenolic nature influences many physiological processes such as, seed germination (Cutt and Klessing, 1992), ion permeability (Barkosky and Einhelling, 1993), photosynthesis and plant growth rate (Khan and Abdullah, 2003; Mahmood *et al*., 2010; Rafique *et al*., 2011). Salicylic acid also prevents the damaging action of various stress factors in many plant species (Sakhabutdinova *et al.*, 2003; Afzal *et al.*, 2005; Iqbal and Ashraf, 2010b). Ascorbic acid (AsA), another important organic molecule serves as detoxification of reactive oxygen species (Conklin and Barth, 2004; Khan *et al*., 2006) and a co-factor for many enzymes (Arrigoni and De Tullio, 2000). It is also involved in biosynthesis of many other plant hormones, including ethylene, gibberellic acid, and abscisic acid (Barth *et al.*, 2006).

Ascorbic acid and salicylic acid and their related components have been reported to induce significant effects during environmental stress (Khan *et al*., 2006; Wang and Li 2006; Hamid *et al.*, 2008; Wang *et al.*, 2009). Harris *et al.*, (1999) found that $CaCl_2$ as effective chemical to alleviate the adverse effects of salt stress on maize at germination stage.

The research work with respect to the possibilities of overcoming temperature stress is limited. So the present study was conducted to know the influence of priming treatments on temperature stress tolerance during seed germination of paddy.

## Materials and Methods

The laboratory experiment was carried out at the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore during 2012-13. Genetically pure seeds of six popular varieties of paddy were obtained from Department of Rice, Coimbatore. The experiment was carried out with four replications in Factorial Completely Randomised Block Design. Seeds were surface sterilized and treated with different chemicals. Appropriate amount of chemicals was directly dissolved in double distilled water. and seeds were soaked in those chemical solutions for 12 h. After priming, the seeds were removed from the solutions, rinsed in water, shade dried at room temperature and subjected to germination test as outlined by ISTA (2004). The unprimed seeds were used as control.

***Germination test :*** Germination test was conducted following the method outlined by ISTA (2004) at three different temperatures i.e., $30^0$C, $38^0$C and $43^0$C. Different temperatures were adjusted in the cabinet germinator. The number of normal seedlings was recorded on the day of final count i.e 14days after sowing.

***Speed of germination :*** Germination counts were recorded every day from the samples which were kept for germination until the germination was completed (Maguire, 1962).

Speed of germination = (n/t)

Where, n = number of seeds newly germinating at time ‘t’

t = days from sowing

***Root length :*** At the time of germination final count, ten normal seedlings were selected at random from each replication and used for measuring the root length of seedlings. Root length was measured from the point of attachment of seed to the tip of primary root. The mean values were calculated and expressed in centimetre.

***Shoot length :*** The seedlings used for measuring root length were also used for measuring shoot length. The shoot length was measured from the point of attachment of seed to tip of the leaf and the mean values were expressed in centimetre.

***Drymatter production :*** Ten normal seedlings were placed in a paper cover and dried in shade for 24h and then, they were kept in an oven maintained at 80°C for 16±1h. The dried seedlings were weighed and the mean values were expressed in g 10 seedlings$^{-1}$.

***Vigour index (VI) :*** The vigour index was calculated using the formula suggested by Abdul-Baki and Anderson (1973).

V. I. = Germination (%) x Dry matter (mg/10 seedlings)

PRINT ISSN.: 0974-1712 ONLINE ISSN.: 2230-732X  

***α- amylase activity***

500mg of pregerminated seed samples were homogenised in 1.8ml of cold 0.02M sodium phosphate buffer (pH 6.0) and centrifuged at 20,000 rpm for 20 min. to extract enzymes. To 0.1ml of enzyme extract, one ml 0.067 per cent starch solution was added. The reaction was stopped after 10 min. of incubation at 25°C by the addition of one ml of iodine HCl solution (60mg KI and 6mg $I_2$ in 100ml of 0.05N HCl). Change in colour was measured at 620nm. The activity was calculated and expressed as mg maltose $min^{-1}$ (Paul *et al.*, 1970).

$$\alpha\text{- Amylase activity} = \frac{\text{OD value}}{\text{Volume of sample pipetted out}} \times \frac{1000}{500}$$

***Statistical analysis***

The data obtained from different experiments were analysed by the 'F' test of significance following the methods described by Panse and Sukhatme (1985).

## Results and Discussion

All the traits under study, including seed germination percentage, speed of germination, root length, shoot length, seedling length, seedling dry weight and seedling vigour index were influenced by temperature stress, priming and cultivar. Moreover, there was a significant three-way interaction (temperature stress × priming × cultivar) for traits like germination per cent, dry matter production and vigour index at the 0.05 level of probability. In general, seed germination percentage significantly decreased when temperature level was increased (Table 1). However, the cultivars did not show similar responses to the increased level of temperature. Priming of seed with ascorbic acid @ 200ppm and salicylic acid @ 50ppm were very effective in increasing germination per cent compared to other treatments under high temperature. These results are similar with observations of Ruan *et al*., (2002) and Mathew & Mohanasarida, (2005), who reported that priming techniques were effective to some extent in increasing germination and early seedling growth of rice. However, the per cent increase varied with the varieties. In CO 47 variety the highest increase in germination % was observed at $43^0$C with the priming of ascorbic acid. In addition, available scattered information suggests that the reason for difference in germination response may be related to seed structure and chemical composition (Khan *et al*., 2006). Increasing temperature between base and optimum temperatures increased the rate of germination and total percentage germination, but temperatures above optimum decrease the germination percentage (Prasad *et al*., 2006).

The difference in speed of germination was statistically significant for the priming treatment, level of temperature and its interaction (Fig 1). The results can be related to early findings in which Essemine *et al*., (2010) observed that very HT (45°C) did not allow adequate speed of germination due to cell death and embryo damage in T. Aestivum during the early stage of development.

Seedling parameters were also affected due to priming treatments and with different temperatures as well. Ascorbic acid @ 200ppm recorded highest shoot length, root length in all varieties followed by salicylic acid and citric acid. Shoot length of proline, calcium chloride and $Na_2HPO_4$ treated seeds was on par (Fig 2).

Maximum dry weight of seedlings caused by seed priming with 200ppm ascorbic acid (Fig 3). Antioxidant nature and increase of plantlet water imbibitions ability in presence of ascorbic acid increased the seedling dryweight (Muller *et al*., 2004). As ascorbic acid could able to increase the speed of germination it also resulted in increase of seedling dry weight. Other treatments like salicylic acid (50ppm) and proline (0.2%) also had favourable effects on dry weight of seedling in temperature stress condition. These findings are in accordance with Afzal *et al*., (2005) who has reported a significant increase in root and shoot length and fresh and dry weight of seedlings by exogenously application of ascorbic acid under both normal and stress conditions. Exogenously applied ascorbic acid has been suggested to be utilized in cell metabolism and to enhance the cell division efficacy of competent cells (Citterio *et al*., 1994).

Seedling vigour severely reduced in temperature stress condition. Maximum seed vigour was by ascorbic acid @ 200ppm and salicylic acid pretreatment (Table 2). These results are analogy with finding obtained by other authors Piramila *et al*., (2012) who showed that seed germination as well as vigour index was significantly reduced by high temperature in blackgram.

α- amylase activity was significantly higher in primed seed compared to the control irrespective of the chemical (Fig 5). This may be the probable reason for improvement of germination and related parameters in primed seed compared to control. Ascorbic acid recorded highest α-amylase activity followed by salicylic acid. The enhancement in α-amylase activity in primed seeds may

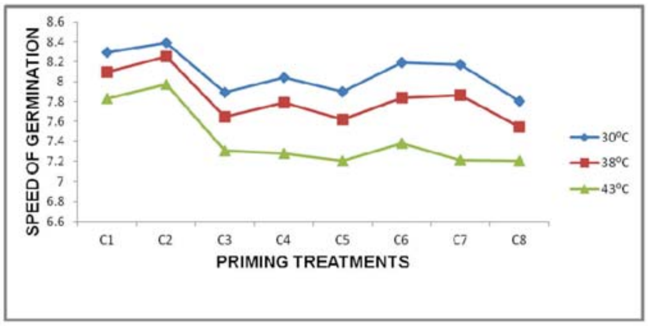
 

**Table 1:** Effect of priming treatments on germination % of six paddy varieties under three levels of temperature.

| Variety \ Treatment | | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| **ADT 43** | **$30^0$C** | 95 (77.08) | 97 (80.03) | 93 (74.99) | 94 (75.55) | 93 (74.99) | 94 (75.55) | 93 (74.99) | 90 (71.65) | **93 (74.99)** |
| | **$38^0$C** | 93 (74.99) | 96 (78.47) | 88 (69.90) | 91 (72.48) | 90 (71.65) | 89 (70.64) | 90 (71.65) | 86 (68.22) | **90 (71.65)** |
| | **$43^0$C** | 90 (71.65) | 93 (74.99) | 85 (67.21) | 86 (68.22) | 87 (68.72) | 84 (66.42) | 85 (67.21) | 81 (64.16) | **86 (68.02)** |
| **Mean** | | **93 (74.99)** | **95 (77.08)** | **89 (70.64)** | **90 (71.65)** | **90 (71.65)** | **89 (70.64)** | **89 (70.64)** | **86 (68.02)** | **90 (71.65)** |
| **ADT 46** | **$30^0$C** | 96 (78.47) | 98 (81.87) | 92 (73.08) | 87 (69.73) | 91 (72.48) | 94 (75.55) | 94 (75.55) | 90 (71.65) | **93 (74.99)** |
| | **$38^0$C** | 94 (75.55) | 97 (80.03) | 88 (69.90) | 84 (66.42) | 89 (70.64) | 90 (71.65) | 90 (71.65) | 86 (68.02) | **90 (71.65)** |
| | **$43^0$C** | 91 (72.48) | 95 (77.08) | 82 (64.89) | 81 (64.16) | 86 (68.02) | 86 (68.02) | 86 (68.02) | 82 (64.89) | **86 (68.02)** |
| **Mean** | | **94 (75.55)** | **97 (80.03)** | **87 (68.72)** | **84 (66.42)** | **89 (70.64)** | **90 (71.65)** | **90 (71.65)** | **86 (68.02)** | **90 (71.65)** |
| **BPT 5204** | **$30^0$C** | 95 (77.08) | 97 (80.03) | 94 (75.55) | 94 (75.55) | 95 (77.08) | 94 (75.55) | 95 (77.08) | 94 (75.55) | **95 (77.08)** |
| | **$38^0$C** | 92 (73.08) | 94 (75.55) | 92 (73.08) | 88 (69.90) | 90 (71.65) | 90 (71.65) | 93 (74.99) | 90 (71.65) | **91 (72.48)** |
| | **$43^0$C** | 89 (70.64) | 92 (73.08) | 86 (68.02) | 82 (64.89) | 86 (68.02) | 85 (67.21) | 89 (70.64) | 85 (67.21) | **87 (68.72)** |
| **Mean** | | **92 (73.08)** | **94 (75.55)** | **91 (72.48)** | **88 (69.90)** | **90 (71.65)** | **90 (71.65)** | **92 (73.08)** | **90 (71.65)** | **91 (72.48)** |
| **CO (R)50** | **$30^0$C** | 97 (80.03) | 97 (80.03) | 95 (77.08) | 89 (70.64) | 89 (70.64) | 94 (75.55) | 93 (74.99) | 89 (70.64) | **93 (74.99)** |
| | **$38^0$C** | 95 (77.08) | 96 (78.47) | 88 (69.90) | 84 (66.42) | 84 (66.42) | 88 (69.90) | 87 (68.72) | 85 (67.21) | **88 (69.90)** |
| | **$43^0$C** | 91 (72.48) | 92 (73.57) | 82 (64.89) | 81 (64.16) | 81 (64.16) | 83 (65.65) | 81 (64.16) | 79 (62.73) | **84 (66.42)** |
| **Mean** | | **94 (75.55)** | **95 (77.08)** | **95 (77.08)** | **85 (67.21)** | **85 (67.21)** | **88 (69.90)** | **87 (68.72)** | **84 (66.42)** | **88 (69.90)** |
| **CO 47** | **$30^0$C** | 98 (81.87) | 99 (84.26) | 94 (75.55) | 94 (75.55) | 89 (70.64) | 95 (77.08) | 93 (74.99) | 87 (68.72) | **93 (74.99)** |
| | **$38^0$C** | 95 (77.08) | 97 (80.03) | 89 (70.64) | 91 (72.48) | 84 (66.42) | 88 (69.90) | 89 (70.64) | 81 (64.16) | **89 (70.64)** |
| | **$43^0$C** | 92 (73.57) | 94 (75.55) | 85 (67.21) | 87 (68.72) | 81 (64.16) | 82 (64.89) | 83 (65.65) | 77 (61.34) | **81 (64.16)** |
| **Mean** | | **95 (77.08)** | **97 (80.03)** | **97 (80.03)** | **91 (72.48)** | **85 (67.21)** | **88 (69.90)** | **88 (69.90)** | **82 (64.89)** | **88 (69.90)** |
| **TKM 9** | **$30^0$C** | 94 (75.55) | 95 (77.08) | 89 (70.64) | 91 (72.48) | 95 (77.08) | 90 (71.65) | 90 (71.65) | 89 (70.64) | **91 (72.48)** |
| | **$38^0$C** | 91 (72.48) | 93 (74.99) | 84 (66.42) | 87 (68.72) | 90 (71.65) | 85 (67.21) | 83 (65.65) | 83 (65.65) | **87 (68.72)** |
| | **$43^0$C** | 88 (69.90) | 90 (71.65) | 79 (62.72) | 81 (64.15) | 83 (65.65) | 79 (62.72) | 76 (60.66) | 77 (61.34) | **81 (64.15)** |
| **Mean** | | **91 (72.48)** | **93 (74.99)** | **93 (74.99)** | **86 (68.02)** | **89 (70.64)** | **85 (67.21)** | **83 (65.65)** | **83 (65.65)** | **86 (68.02)** |
| | | | | **V** | | **C** | **T** | **VxCxT** | | |
| **SEd** | | | | **0.18** | | **0.21** | **0.13** | **0.89** | | |
| **CD (P=0.05)** | | | | **0.36** | | **0.42** | **0.25** | **1.75** | | |

C1=Salicylic acid; C2 = Ascorbic acid; C3 = Proline; C4 = Citric acid
C5= Calcium chloride; C6= $Na_2HPO_4$; C7 = Distilled water; C8= control




C1=Salicylic acid; C2 = Ascorbic acid; C3 = Proline; C4 = Citric acid
C5= Calcium chloride; C6= $Na_2HPO_4$; C7 = Distilled water; C8= control

**Fig 1:** Effect of priming treatments on speed of germination of paddy varieties at three different temperatures

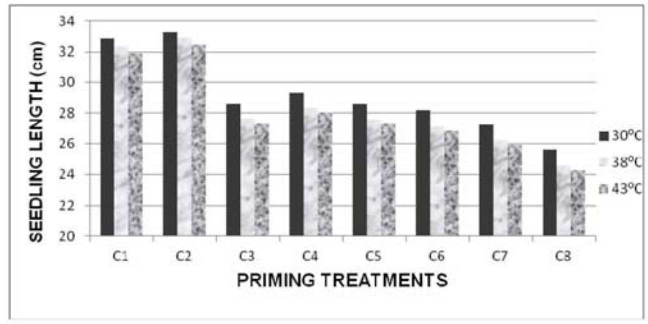



**Fig 2:** Effect of priming treatments on seedling length of paddy varieties at three different temperatures.

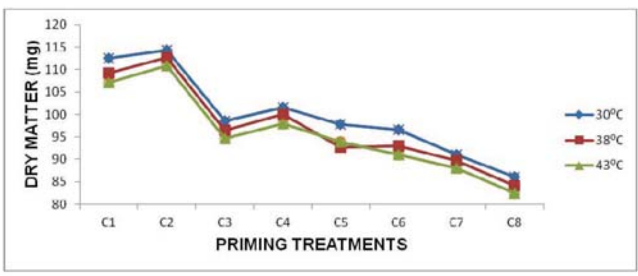



**Fig 3:** Effect of priming treatments on drymatter content of paddy varieties at three different temperatures

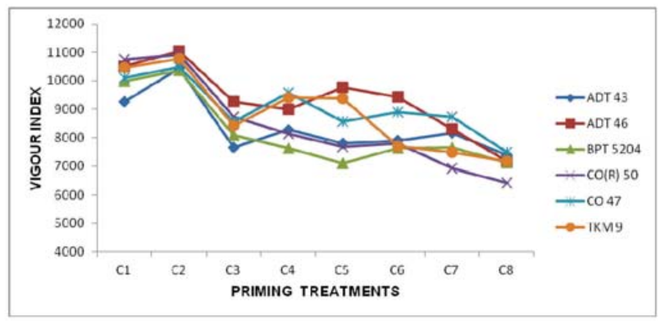



**Fig 4:** Effect of priming treatments on vigour index of six paddy varieties

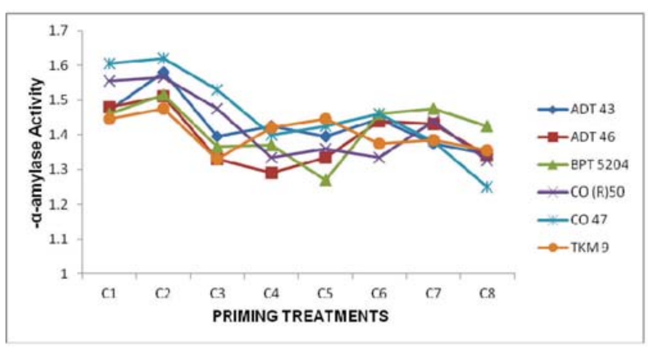



**Fig 5:** Effect of priming treatments on á- amylase activity of six paddy varieties

**Table 2:** Effect of priming treatments on vigour index of six paddy varieties under three levels of temperature

| Variety \ Treatment | | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| **ADT 43** | **30$^0$C** | 10277 | 10898 | 8186 | 8779 | 8314 | 8544 | 8638 | 7964 | **8950** |
| | **38$^0$C** | 8963 | 10415 | 7603 | 8361 | 7740 | 7867 | 8216 | 7352 | **8314** |
| | **43$^0$C** | 8521 | 10011 | 7199 | 7719 | 7343 | 7290 | 7580 | 6867 | **7816** |
| **Mean** | **9254** | **10441** | **7663** | **8226** | **7799** | **7900** | **8145** | **7394** | **8360** | |
| **ADT 46** | **30$^0$C** | 10997 | 11363 | 9886 | 9482 | 10121 | 10028 | 8900 | 7695 | **9806** |
| | **38$^0$C** | 10513 | 11150 | 9358 | 9011 | 9819 | 9419 | 8314 | 7198 | **9347** |
| | **43$^0$C** | 9995 | 10625 | 8538 | 8506 | 9376 | 8835 | 7693 | 6625 | **8774** |
| **Mean** | **10502** | **11046** | **9261** | **9000** | **9772** | **9427** | **8302** | **7173** | **9309** | |
| **BPT 5204** | **30$^0$C** | 10446 | 10860 | 8555 | 8257 | 7726 | 8020 | 7736 | 7623 | **8653** |
| | **38$^0$C** | 10005 | 10363 | 8180 | 7655 | 7049 | 7722 | 7836 | 7157 | **8245** |
| | **43$^0$C** | 9491 | 9914 | 7506 | 6944 | 6546 | 7122 | 7396 | 6592 | **7689** |
| **Mean** | **9981** | **10379** | **8080** | **7619** | **7107** | **7621** | **7656** | **7124** | **8196** | |
| **CO (R)50** | **30$^0$C** | 11140 | 11324 | 9542 | 8696 | 8213 | 8976 | 7572 | 6979 | **9055** |
| | **38$^0$C** | 10891 | 11006 | 8726 | 8045 | 7594 | 7550 | 6909 | 6478 | **8400** |
| | **43$^0$C** | 10259 | 10399 | 7933 | 7642 | 7238 | 6888 | 6294 | 5846 | **7812** |
| **Mean** | **10763** | **10910** | **8734** | **8128** | **7682** | **7805** | **6925** | **6434** | **8422** | |
| **CO 47** | **30$^0$C** | 10649 | 10857 | 9161 | 10054 | 9163 | 9636 | 9372 | 8124 | **9627** |
| | **38$^0$C** | 10105 | 10521 | 8550 | 9632 | 8537 | 8909 | 8740 | 7424 | **9052** |
| | **43$^0$C** | 9583 | 10091 | 8004 | 9051 | 8012 | 8136 | 8080 | 6888 | **8480** |
| **Mean** | **10112** | **10490** | **8572** | **9579** | **8571** | **8894** | **8731** | **7479** | **9053** | |
| **TKM 9** | **30$^0$C** | 10935 | 11118 | 9136 | 10041 | 10145 | 8652 | 8268 | 7805 | **9512** |
| | **38$^0$C** | 10485 | 10837 | 8379 | 9457 | 9437 | 7561 | 7447 | 7145 | **8843** |
| | **43$^0$C** | 9972 | 10406 | 7760 | 8713 | 8550 | 6858 | 6760 | 6550 | **8196** |
| **Mean** | **10464** | **10787** | **8425** | **9404** | **9377** | **7690** | **7492** | **7167** | **8850** | |
| | **V** | **C** | **T** | **VxCx** | | | | | | |
| **TSEd** | **7.90** | **9.12** | **5.59** | **38.70** | | | | | | |
| **CD** | **15.53** | **17.93** | **10.98** | **76.08** | | | | | | |

be attributed to proper hydration during imbibition that increased the starch hydrolysis and the effect of the increased starch hydrolysis due to hydration treatments was not lost during the redrying process (Afzal *et al.*, 2008). Similar results were also obtained by Lee and Kim (2000) in rice.

In conclusion, this study shows that the ascorbic acid and salicylic acid priming increased the temperature tolerance of rice seedlings demonstrated by improving germination per cent, speed and shoot and root growth and enzyme activity.

## Acknowledgements

We are thankful to Department of Science and Technology, Govt. of India for providing financial assistance under Innovation in Science Pursuit for Inspired Research (INSPIRE) programme and also to Dr. Robin for providing seed material and members of advisory committee for their valuable guidance.

## References

Abdul-Baki, A.A., and J.D. Anderson. 1973. Vigour deterioration of soybean seeds by multiple criteria. *Crop Science* **13**: 630-633.

Afzal, I.M., B.N. Shahzad., Ahmad., M.F. Ahmad. 2005. Optimization of hormonal priming techniques for alleviation of salinity stress in wheat (Triticum aestývum *L.*). *Caderno de Pesquisa Sér. Bio. Santa Cruz do Sul* **17**: 95-109.

Afzal, I, S.M.A. Basra., M. Shahid., M. Farooq., and M. Saleem. 2008. Priming enhances germination of spring maize (*Zea mays L.*) under cool conditions. *Seed Science & Technology* **36**: 497-503.

Arrigoni, O., De., and M.C. Tullio. 2000. The role of ascorbic acid in cell metabolism: between gene-directed functions and unpredictable chemical reactions. *Journal of Plant Physiology* **157**: 481-488.

Barkosky, R.R., and F.A. Einhellig. 1993. Effects of salicylic acid on plant water relationship. *Journal of Chemical Ecology* **19**: 237-247.

Barth, D.E., M. Tullio., and P.L. Conklin. 2006. The role of ascorbic acid in the control of flowering time and the onset of senescence. *Journal of Experimental Botany* **57**: 1657-1665.

Basra, S.M.A., M. Farooq., and R. Tabassum. 2005. Physiological and biochemical aspects of seed vigor enhancement treatments in fine rice (*Oryza sativa* L). *Seed Science and Technology* **33**: 623-628.

Castellani, E., and I. Aguiar. 2001. Seed maturation and eûect of temperature regime on *Trema micrantha* (L.) Blume seed germination. *Seed Science and Technology* **29**: 73–82.

Citterio, S., S. Sgorbati., S. Scippa., and E. Sparvoli. 1994. Ascorbic acid effect on the onset of cell proliferation in pea root. *Physiologia Plantarum* **92**: 601-607.

Conklin, P.L., and C. Barth. 2004. Ascorbic acid, a familiarsmall molecule intertwined in the response of plants to ozone, pathogens and the onset of senescence. *Plant Cell Environment* **27**: 959-971.

Cutt, J.R., and D.F. Klessing. 1992. Salicylic acid in plants. A changing perspective. *Pharmaceutical Science and Technology* **16**: 25-34.

Essemine, J., S. Ammar., S. Bouzid. 2010. Impact of heat stress on germination and growth in higher plants: Physiological, biochemical and molecular repercussions and mechanisms of defence. *Journal of Biological Sciences* **10**: 565-572.

Farooq, M, S.M.A. Basra., and N. Ahmad. 2007b. Improving the performance of transplanted rice by seed priming. *Plant Growth Regulation* **51**: 129-137.

Farooq, M, S.M.A. Basra., R. Hafeezu., and B.A. Saleem. 2008. Seed priming enhances the performance of late sown wheat (Triticum estivum L.) by improving chilling tolerance. *Journal of Agronomy and Crop Science* **194(1)**: 55-60.

Farooq, M., S.M.A. Basra, R. Tabassum., and Afzal, I. 2006b. Enhancing the performance of direct seeded fine rice by seed priming. *Plant Production Science* **9**: 446-456.

Ferrari, L., and C. Lopez. 2000. Germination conditions for *Briza subaristata*: pretreatments and temperature eûects. *Seed Science and Technology* **28**: 631–639

Hamid, M., M.Y. Ashraf, R.K. U.r, and M. Arashad. 2008. Influence of salicylic acid priming on growth and some biochemical attributes in wheat grown under saline conditions. *Pakistan Journal of Botany* **40**: 361-367.

Harris, D., A. Joshi, P.A. Khan., P. Gothkar., and P.S. Sodhi. 1999. On-farm seed priming in semi-arid agriculture: Development and evaluation in maize, rice and chickpea in India using participatory methods. *Experimental Agriculture* **35**: 15-29.

Iqbal, M., and Ashraf, M. 2010b. Changes in hormonal balance: A possible mechanism of re-sowing chilling-induced salt tolerance in spring wheat. *Journal of Agronomy and Crop Science* **196:** 440-454.

Janmohammadi, M., D. Moradi, F. Sharifzadeh. 2008. Seed invigoration techniques to improve germination and early growth of inbred line of maize under salinity and drought stress. *General and Applied Plant Physiology* **34**(3-4): 215-226.

Kaur, S., Gupta, A.K., and Kaur, N. 2005. Seed priming increases crop yield possibly by modulating enzymes of sucrose metabolism in chickpea. *Journal of Agronomy and Crop Science*. **191**: 81-87.

Khan, A., M.S.A. Ahmad., H.R. Athar., and M. Ashraf. 2006. Interactive effect of foliar applied ascorbic acid and salt stress on wheat (*Triticum aestivum* L.) at seedling stage. *Pakistan Journal of Botany* **38**(5): 1407-1414.

Khan, M.A., and Z. Abdullah. 2003. Salinity-sodicity induced changes in reproductive physiology of rice (*Oryza sativa*) under dense soil conditions. *Environmental and Experimental Botany* **49**: 145-157.

Lee, S.S., and J.H. Kim. 2000. Total sugars, á-amylase activity and germination after priming of normal and aged rice seeds. *Korean Journal of Crop Sciences* **45**: 108-111.

Maguire, J.D. 1962. Speed of germination - Aid in selection and evaluation of seedling emergence and vigour. *Crop Science* **2**: 176-177.

Mahmood T, Iqbal N, Raza H, Qasim M, Ashraf M.Y. 2010. Growth modulation and ion partitioning in salt stressed sorghum (sorghum bicolour L.) by exogenously supply of salicylic acid. *Pakistan Journal of Botany* **42**: 3047-3054.

Mathew, J., and K. Mohanasarida . 2005. Seed priming on crop establishment and seedling vigour in semi-dry rice (*Oryza sativa*). *Research on Crops* **6**: 23-25.

Muller-Moule, P., T. Golan., and K.K. Niyogi. 2004. Ascorbate-deficient mutants of Arabidopsis grow in high light despite chronic photooxidative stress. *Plant Physiology* **134**: 1163–1172.

Murungu, F.S., C. Chiduza., P. Nyamugafata., L.J. Lark., W.R. Whalley., and W.E. Finch-Savage. 2004. Effects of on- farm seed priming on consecutive daily sowing occasions on the emergence and growth of maize in semi-arid Zimbabwe. *Field Crops Research* **89 :** 49-57.

Panse, V.G., and P.V. Sukatme. 1985. Statistical methods for agricultural workers. ICAR publication, New Delhi, 359.

Paul A.K., S. Mukh Erji., and S.M. Sircar. 1970. Metabolic changes in rice seeds during storage. *Indian Journal of Agricultural Sciences* **40(12)**: 1031-1036.

Piramila, B.H.M., A.L. Prabha., V. Nandagopalan., and A.L. Stanley. 2012. Effect of heat treatment on germination, seedling growth and some biochemical parameters of dry seeds of black gram. *International Journal of Pharmaceutical and Phytopharmacological Research* **1**: 194-202.

Prasad, P.V.V., Boote, K.J., and L.H. Allen Jr. 2006. Adverse high temperature effects on pollen viability, seed-set, seed yield and harvest index of grain-sorghum [*Sorghum bicolour* (L.) Moench]. are more severe at elevated carbon dioxide due to higher tissue temperatures. *Agricultural and Forest Meteorology* **139**: 237-251.

Rafique, N., H. Raza., H. Qasim., and N, Iqbal. 2011. Pre-sowing application of ascorbic acid and salicylic acid to seed of pumpkin and seedling response to salt. *Pakistan Journal of Botany* **43**: 2677-2682.

Ruan, S., Q. Xue., and R. Tylkowska. 2002. Effects of seed priming on germination and health of rice (*Oryza sativa* L.) seeds. *Journal of Seed Science and Technology* **30** :451-458.

Sakhabutdinova, A.R., D.R. Fatkhutdinova., M.V. Bezrukova., and F.M. Shakirova. 2003. Salicylic acid prevents the damaging action of stress factors on wheat plants. *Bulgarian Journal of Plant Physiology*, Special Issue 314–319.

Tavili, A., S. Zare., and A. Enayati. 2009. Hydropriming, Ascorbic and Salicylic acid Influence on germination of *Agropyron elongatum* Host. Seeds Under Salt Stress. *Research Journal of Seed Science* **2(1)**: 16-22.

Wang, L.J., and S.H. Li. 2006. Thermotolerance and related antioxidant enzyme activities induced by heat acclimation and salicylic acid in grape (*Vitis vinifera* L.) leaves. *Plant growth Regulation* **48**: 137-144.

Wang, W.B., Y.H. Kim., H.S. Lee., K.Y. Kim., X.P. Deng., and S.S. Kwak . 2009. Analysis of antioxidant enzyme activity during germination of alfalfa under salt and drought stresses. *Plant Physiology and Biochemistry* **47**: 570-577.

PRINT ISSN.: 0974-1712 ONLINE ISSN.: 2230-732X  