Evaluation of Physiological and Biochemical Parameters of Some Wheat (*Triticum aestivum*) Genotypes under Salinity Stress

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**ABSTRACT**

Physiological and biochemical parameters of plants among five wheat genotypes: KH-65, KRL-210, KRL-99, PBW-343 and PBW-373 were studied. Wheat plantlets, at three-leaf stage, were supplemented with 0, 50, 100, 150, 200, 250 and 300 mM of NaCl for 48 hours. Principal component analysis revealed chlorophyll and carotenoid degradation as best salinity indicator for studied wheat genotypes. Salt tolerance levels of studied wheat genotypes were in the order: KH-65 > KRL-210 > KRL-99 > PBW-343 > PBW-373. The study has revealed that observed physiological and biochemical data may provide an insight into the existence of internal mechanism in salt tolerant genotypes to cope up with salinity stress.

**Key words:** Biochemical, Genotypes, Physiological, Salinity, Tolerance, *Triticum aestivum*.

**INTRODUCTION**

Wheat, the first domesticated plant is a basic staple food crop consumed globally by 1/3rd of population. Its cultivation occupies 240 million hectares of land, worldwide, which is more than for any other commercial crop (F.A.O., 2013). The salinity stress is a prominent abiotic factor that limits the growth and productivity of wheat plant (Zörb et al. 2019). The decreased plant growth under salinity stress is due to diminished nutrient uptake, lower photosynthetic rate, slower cell division, hyper generation of ROS (Reactive oxygen species) and increased energy loss due to salt exclusion mechanism (Long and Baker, 1986; Zörb et al., 2019). For a further insight into the mechanism of salinity stress on plants and its possible remediation, it is important to study physiological and biochemical parameters (Kumar et al. 2017).

Proline, an important osmolyte which accumulates inside plants, is known for providing cellular homeostasis during salinity stress (Ramanjulu and Sudhakar, 2001). The presence of hydrogen peroxide a signaling molecule in plants, during stress conditions, generates harmful hydroxyl radicals which are toxic to plant cells (Velikova et al., 2000; Petrov and Van Breusegem, 2012). Significant work has been reported in physiological and biochemical parameters under salinity stress during germination and seedling growth of plants (Bafeel, 2014, Zörb et al., 2019, Wani and Gupta, 2018). The lipid peroxidation levels in leaflets of two contrasting wheat lines were studied under salinity stress and their response at different developmental stages was recorded by Ashraf et al. (2010). Wani and Gupta (2018) studied many different biochemical analysis (production of ROS and nitric oxide) along with expression of antioxidant genes in some wheat tissues. Similarly, Kumar et al. (2017) also noticed genotypic differences while studying physiological and biochemical parameters in response to drought and salinity stress in rice genotypes. In continuance of the above experiments, this study was undertaken to evaluate salinity effects on physiological and biochemical parameters of some contrasting wheat genotypes.

The outline of study was carried out to explore the effects of salinity stress on some physiological and biochemical parameters of the selected wheat genotypes is given in Fig 1.

**MATERIALS AND METHODS**

Seeds of wheat genotypes KH-65, KRL-210, KRL-99, PBW-343 and PBW-373 were kindly provided by the Indian Institute of Wheat and Barley Research (IIWBR) Karnal and Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana, India.

The seeds of wheat genotypes were sterilized by 0.1% HgCl2 aqueous medium for a time period of 5 minutes and then rinsed, thrice. The sterilized seeds were imbibed in distilled water for two hours and allowed to germinate in autoclaved sand. These were then transferred to hydroponic culture media for 48 hours prior to their saline treatment in...
a growth chamber. The seedlings at three-leaf-stage were treated with 50, 100, 150, 200, 250 and 300mM NaCl prepared in half strength of modified Hoagland solution (Jones, 1982). The plants were allowed to grow for 48 hours at 20°C under 16 hours light and 8 hours dark photoperiod per day at 2000 lux (Wang et al. 2008) and the plantlets were then harvested.

The roots and shoots of seedlings were weighed accurately, within ± 0.01mg, using an analytical balance (METTLER TOLEDO, Model: ML204 /A01) and the average of triplicate measurements was taken. The lengths of shoots or roots of seedlings were measured in cm within ±0.1 mm using a standard meter scale. Total chlorophylls and carotenoids concentrations and their percent loss in studied wheat genotypes were determined, spectrophotometrically as described by Costache et al. 2012 and Hussain et al. 2006. Proline levels were measured according to Bates et al. 1973. Modified method of Heath and Packer (1968) was used for the evaluation of lipid peroxidation levels by measuring MDA (malonyldialdehyde) content. Hydrogen Peroxide ($\text{H}_2\text{O}_2$) concentrations were obtained by using a method of Velikova et al. (2000).

The observed physiological and biochemical data were subjected to statistical analysis by using ANOVA. All the variables in the recorded data are presented as mean ± standard deviation. The data when subjected to one-way ANOVA was found statistically significant. Principal component analysis (PCA) was done to find the independent predictor of analysis with the help of SPSS-16.

**RESULTS AND DISCUSSION**

**Effect of salinity stress on plant phenotypic parameters**

Physiological parameters i.e. shoot heights, root lengths, shoot weights and root weights of plantlets in studied wheat genotypes treated with varying salinity levels at 48 hours of growth are compared in Table 1 to 4. Significantly differential effects in their values were observed on varying salinity stress level (p<0.0001) and these parameters were negatively affected by increasing salinity stress. These parameters were considered at 5% level of percentage decrease. In shoot height (Table 1), KH-65 shows the least variation with increasing stress levels. At the same time two cultivars KRL-210 and KRL-99 show the significant reduction at 150mM and 100mM respectively. However, the sensitive cultivars i.e. PBW-343 and PBW-373 show the critical levels at 50mM only. Similarly, critical decrease for root length (Table 2) was shown at 100mM in KRL-210 and KRL-99 whereas PBW-343 and PBW-373 shows same decrease at 50mM. Plant weight is most sensitive character in relation to salt stress in both shoot (Table 3) and root (Table 4). The cultivars showed almost the same trend. KRL-99, PBW-343 and PBW-373 achieved the 5% decrease at initial level of stress application i.e. at 50mM in both cases. Shoot weight shows same level in KH-65 and KRL-210 at 150mM and 100mM treatment respectively whereas in root same level was found at 100mM for both KH-65 and KRL-210. The observed decrease in these physiological parameters upon enhancing salinity level may be due to the toxic effects
Table 1: Shoot height (cm) of seedlings of five contrasting wheat genotypes after 48 hours of salt stress treatment.

| Wheat genotypes | Salinity tolerance | NaCl concentration (mM) | 0 | 50 | 100 | 150 | 200 | 250 | 300 |
|-----------------|--------------------|--------------------------|---|----|-----|-----|-----|-----|-----|
| KH-65           | HT                 | 16.00 ± 0.500            | 15.83 ± 0.764 | 15.40 ± 1.153 | 15.33 ± 0.764 | 15.67 ± 2.466 | 15.17 ± 1.041 | 15.03** ± 0.153 |
| KRL-210         | T                  | 20.83 ± 0.481            | 20.27 ± 0.804 | 19.97 ± 1.145 | 19.17** ± 0.536 | 19.03** ± 0.051 | 18.97* ± 2.072 | 18.88* ± 0.752 |
| KRL-99          | T                  | 19.80 ± 1.044            | 18.93 ± 1.002 | 18.23** ± 0.153 | 17.37* ± 1.250 | 15.33* ± 0.839 | 15.00* ± 0.265 | 14.30* ± 1.082 |
| PBW-343         | S                  | 23.00 ± 1.500            | 21.67** ± 2.082 | 20.77** ± 2.039 | 19.80* ± 1.836 | 17.33* ± 1.528 | 15.83* ± 0.764 | 15.33* ± 0.577 |
| PBW-373         | S                  | 20.83 ± 1.443            | 19.00** ± 0.866 | 18.50* ± 1.323 | 17.67* ± 0.577 | 15.33* ± 1.155 | 15.00* ± 2.000 | 13.33* ± 1.155 |

HT - Highly salt tolerant; T - Salt tolerant; S - Salt sensitive; **- Significantly different at 5%; *-Highly significant at 10%.

Table 2: Root length (cm) of seedlings of five contrasting wheat genotypes after 48 hours of salt stress treatment.

| Wheat genotypes | Salinity tolerance | NaCl concentration (mM) | 0 | 50 | 100 | 150 | 200 | 250 | 300 |
|-----------------|--------------------|--------------------------|---|----|-----|-----|-----|-----|-----|
| KH-65           | HT                 | 9.20 ± 1.311             | 9.17 ± 0.764 | 9.07 ± 0.513 | 9.03 ± 1.343 | 9.00 ± 1.000 | 8.97 ± 0.451 | 8.33 ± 0.764 |
| KRL-210         | T                  | 10.50 ± 0.500            | 10.20 ± 0.306 | 9.83** ± 1.110 | 9.67** ± 0.255 | 9.40* ± 1.258 | 9.33* ± 0.347 | 9.07* ± 0.091 |
| KRL-99          | T                  | 10.27 ± 0.208            | 9.87 ± 0.757 | 9.50** ± 0.300 | 9.43** ± 0.681 | 9.10* ± 3.066 | 9.03* ± 0.153 | 8.82* ± 0.597 |
| PBW-343         | S                  | 13.83 ± 1.893            | 12.90** ± 1.100 | 11.93* ± 1.290 | 11.70* ± 1.570 | 11.00* ± 1.000 | 10.67* ± 1.155 | 9.67* ± 0.577 |
| PBW-373         | S                  | 12.83 ± 0.764            | 11.90** ± 0.656 | 10.93* ± 1.401 | 10.77* ± 1.662 | 10.07* ± 1.102 | 9.83* ± 1.258 | 8.67* ± 0.577 |

HT - Highly salt tolerant; T - Salt tolerant; S - Salt sensitive; **- Significantly different at 5%; *-Highly significant at 10%.

Table 3: Shoot weight (mg) of seedlings of five contrasting wheat genotypes after 48 hours of salt stress treatment.

| Wheat genotypes | Salinity tolerance | NaCl concentration (mM) | 0 | 50 | 100 | 150 | 200 | 250 | 300 |
|-----------------|--------------------|--------------------------|---|----|-----|-----|-----|-----|-----|
| KH-65           | HT                 | 83.10 ± 4.513            | 80.33 ± 2.608 | 79.07 ± 1.320 | 76.67** ± 5.856 | 72.03* ± 1.401 | 64.47* ± 4.163 | 54.7* ± 1.342 |
| KRL-210         | T                  | 180.77 ± 9.234           | 172.00 ± 6.993 | 169.97** ± 21.136 | 169.93** ± 7.786 | 151.3* ± 4.100 | 104.03* ± 16.885 | 99.16* ± 3.353 |
| KRL-99          | T                  | 137.10 ± 8.679           | 120.33* ± 9.862 | 100.43* ± 9.439 | 88.17* ± 3.370 | 87.23* ± 5.714 | 77.06* ± 14.262 | 70.30* ± 6.846 |
| PBW-343         | S                  | 180.60 ± 21.611          | 152.17* ± 10.341 | 129.13* ± 14.611 | 112.37* ± 14.608 | 100.6* ± 16.029 | 94.10* ± 7.538 | 86.50* ± 7.727 |
| PBW-373         | S                  | 141.10 ± 13.735          | 118.6* ± 15.320 | 98.93* ± 6.953 | 90.10* ± 0.953 | 76.3* ± 10.376 | 72.03* ± 10.512 | 63.7* ± 7.543 |

HT - Highly salt tolerant; T - Salt tolerant; S - Salt sensitive; **- Significantly different at 5%; *-Highly significant at 10%.
Table 4: Root weight (mg) of seedlings of five contrasting wheat genotypes after 48 hours of salt stress treatment.

| Wheat genotypes | Salinity tolerance | NaCl concentration (mM) | 0 | 50 | 100 | 150 | 200 | 250 | 300 |
|-----------------|--------------------|-------------------------|---|----|-----|-----|-----|-----|-----|
| KH-65           | HT                 | 80.87 ± 3.888           | 86.87 ± 3.888 | 78.23 ± 2.003 | 75.77 ± 2.647 | 73.37 ± 3.550 | 70.19 ± 3.203 | 67.19 ± 3.068 | 64.20 ± 3.068 |
| KRL-210         | T                  | 90.87 ± 6.333           | 83.86 ± 6.333 | 78.23 ± 2.003 | 75.77 ± 2.647 | 73.37 ± 3.550 | 70.19 ± 3.068 | 67.19 ± 3.068 | 64.20 ± 3.068 |
| KRL-99          | T                  | 95.33 ± 2.539           | 87.86 ± 2.539 | 81.33 ± 2.003 | 78.23 ± 2.003 | 75.77 ± 2.647 | 73.37 ± 3.550 | 70.19 ± 3.068 | 67.19 ± 3.068 |
| PBW-343         | S                  | 113.03 ± 9.808          | 104.23 ± 9.808 | 98.73 ± 2.003 | 95.33 ± 2.539 | 92.70 ± 3.550 | 90.17 ± 3.068 | 87.19 ± 3.068 | 84.20 ± 3.068 |
| PBW-373         | S                  | 93.93 ± 5.101           | 86.87 ± 5.101 | 80.87 ± 2.003 | 78.23 ± 2.003 | 75.77 ± 2.647 | 73.37 ± 3.550 | 70.19 ± 3.068 | 67.19 ± 3.068 |

Caused by osmotic stress in the plants, poor nutrient uptake and hampered water uptake process (Datta et al. 2009). Bilkis et al. (2016) reported similar salinity effects on some physiological and agronomic traits of wheat and as per the findings of Byrt et al. (2018) root growth of most of the crop plants is inhibited by soil salinity. The results indicate that salt sensitivity of the studied wheat genotypes are in the order: PBW-373 > PW-343 > KRL-99 > KRL-210 > KH-65. Whereas, PBW-343 and PBW-373 showed high susceptibility to salinity stress even at very low salt concentrations. On the contrary, the genotype KH-65 exhibits highest tolerance even up to 300 mM salinity level.

Effect of salinity stress on plant physiological and biochemical parameters

Estimates of chlorophyll, carotenoids, lipid peroxidation, proline and hydrogen peroxide with varying salt concentration at 48 hours in seedlings of studied wheat genotypes are presented in Fig 2(a) to 2(e), respectively. Chlorophyll as well as carotenoid degradations in the plantlet seedlings at salt levels up to 300 mM were found in the order: PBW-373 > PBW-343 > KRL-99 > KRL-210 > KH-65. As suggested by Ibrahim et al., 2017 and Zhao et al., 2007, higher activity of enzyme chlorophyllase and the decreased rate of chlorophyll synthesis might be responsible for decrease in levels of two pigments at higher salinity concentrations. Similar results on chlorophyll degradation under salinity stress were also reported by other researchers (Sairam et al., 2005; Yildiz and Terzi, 2013). Except chlorophyll and carotenoid content all other biochemical test (lipid peroxidation, proline and hydrogen peroxide) were performed at 0, 100, 200 and 300 mM salinity levels to obtain significant difference.

Lipid peroxidation level in plants is estimated through MDA measurement is an indicator of oxidative stress under salinity conditions. Higher the MDA concentration in a plant more is the oxidative stress as well as its susceptibility towards salinity (Ashraf et al., 2010; Khaliq et al., 2015). Lipid peroxidation levels in KH-65, KRL-210 and KRL-99 are of same level but are lower by 15% and 50% compared to PBW-343 and PBW-373, respectively. Lipid peroxidation has also been used as an essential parameter in grading salinity tolerant genotypes in other crops such as sorghum and barley and concluded similar relationship of lipid peroxidation level with plant tolerance towards salinity (Brankova et al. 2005). Based upon above observation, salinity sensitivity of different wheat lines have been graded as PBW-373 > PBW-343 > KRL-99 ≥ KRL-210 ≥ KH-65.

Different metabolic products accumulated inside plants upon exposure to stress conditions play role plant metabolism e.g., amino acids, precursors of proteins. Proline an important plant osmolyte produced more in stressed conditions provide tolerance to the plants by decreasing oxidative stress (Hayat et al. 2012). Under salinity, proline level increases in cytosol to adjust osmotic imbalance by scavenging ROS produced inside durum wheat (Annunziata et al. 2017). It is also believed that proline being a chaperone...
molecule, improves enzymatic activities by protecting protein structures (Ashraf and Foolad, 2007; Szabados and Savour’e, 2009). Proline level in plants is significantly affected by salinity stress (p < .00001). Higher accumulation of proline in seedlings of salinity-tolerant varieties than salinity-susceptible ones of rice have been reported by Abdelaziz et al. (2018). Our observation on proline accumulation in seedlings of studied wheat genotypes and their salinity tolerance levels may be put in the order as: KH-65 > KRL-210 > KRL-99 > PBW-343 > PBW-373.

Hydrogen peroxide (H$_2$O$_2$) a signaling molecule, generated from plant metabolism is involved in plant development and abiotic responses. Being as ROS, its production increases during stress conditions. Due to its oxidative nature, it imparts toxic effects in plants (Petrov and Breusegem, 2012). Niu and Liao (2016) studied that under stressed conditions H$_2$O$_2$ affects plant processes therefore have impact on plant health. For each studied genotype, the observed H$_2$O$_2$ level increases with the increasing salt concentration and a lower level of H$_2$O$_2$ in plants may be correlated to their higher tolerance to the

**Fig 2:** Estimates of some physiological and biochemical parameters with varying salt concentration at 48 hours in plantlet seedlings of studied wheat genotypes: (a): Chlorophyll, (b): Carotenoids, (c): Lipid peroxidation (d): proline and (e): Hydrogen peroxide.

**Fig 3:** Loading plots of principal components of the principal component analysis (PCA) results obtained from physiological data of five contrasting wheat genotypes subjected to 300mM NaCl concentration level.
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salinity stress (Caverzan et al. 2016). Ali et al. (2017) have also reported higher production of H$_2$O$_2$ levels upon salinity stress in some wheat plantlets. Hydrogen peroxide levels with increasing salinity concentrations at 48 hours inside seedlings of studied wheat genotypes were found in order: PBW-373 > PBW-343 > KRL-99 > KRL-210 > KH-65.

The principal component analysis (PCA) was used as a statistical tool to predict the most contributing factor (Jolliffe, 2002) for comparing levels of salinity tolerance or sensitivity of the studied wheat genotypes. Results of PCA loading plots obtained from biochemical data of five wheat cultivars subjected to salinity stress are presented in Fig 3. It was found that total chlorophyll and carotenoid content are the most susceptible factor for stress in this investigation.

CONCLUSION

The physiological and biochemical parameters under salinity stress in seedlings of wheat genotypes: KH-65, KRL-210, KRL-99, PBW-343 and PBW-373 have been evaluated to assess their sensitivity up to 300mM. A significant correlation was seen among the studied parameters with increasing soil salinity levels. Based upon the observed physiological and biochemical data for the wheat lines, salinity tolerance was found in the order: KH-65 > KRL-210 > KRL-99 > PBW-343 > PBW-373. Therefore, it can be hypothesized that observed varying responses of the wheat genotypes to the salinity stress may be due to their genetic variations and the tolerant lines can be used for farming under salt stress conditions for higher yields.

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REFERENCES

Abdelaziz, M.N., Xuan, T.D., Mekawy, A.M.M., Wang, H., Khanh, T.D. (2018). Relationship of Salinity Tolerance to Na$^+$ Exclusion, Proline accumulation and antioxidant enzyme activity in rice seedlings. Agriculture. 8(11): 166. https://doi.org/10.3390/agriculture8110166.

Ali, Q., Daud, M.K., Haider, M.Z., Ali, S., Rizwan, M., Aslam, N., Noman, A., Iqbal, N., Shahzad, F., Deeba, F. (2017). Seed priming by sodium nitroprusside improves salt tolerance in wheat (Triticum aestivum L.) by enhancing physiological and biochemical parameters. Plant Physiology and Biochemistry. 119: 50-58.

Annunziata, M.G., Ciarniello, L.F., Woodrow, P., Maximova, E., Fuggi, A., Carillo, P. (2017). Durum wheat roots adapt to salinity remodeling the cellular content of nitrogen metabolites and sucrose. Frontiers in Plant Science. 7: 1-16.

Ashraf, M.A., Ashraf, M., Ali, Q. (2010). Response of two genetically diverse wheat cultivars to salt stress at different growth stages: leaf lipid peroxidation and phenolic contents. Pakistan Journal of Botany. 42: 559-565.

Ashraf, M.F.M.R. and Foadad, M. (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environmental and Experimental Botany. 59: 206-216.

Bafeel, S.O. (2014). Physiological parameters of salt tolerance during germination and seedling growth of Sorghum bicolor cultivars of the same subtropical origin. Saudi Journal of Biological Sciences. 21: 300-304.

Bates, L.S., Waldren, R.P. and Teare, I.D. (1973). Rapid determination of free proline for water-stress studies. Plant Soil. 39: 205-207.

Blikis, A., Islam, M.R., Hafiz, M.H.R., Hasan, M.A. (2016). Effect of NaCl induced salinity on some physiological and agronomic traits of wheat. Pakistan Journal of Botany. 48: 455-460.

Brankova, L., Ivanov, S., Alexieva, V., Karanov, E. (2005). Salt-induced alteration in the levels of some oxidative parameters and unspecific defence compounds in leaves of two plant species (cotton and bean) with different sensitivity to salinity. Dokladi na Blgarskata akademija na naukite. 58: 1307-1312.

Byrt, C.S., Munns, R., Burton, R.A., Gilliham, M., Wege, S. (2018). Root cell wall solutions for crop plants in saline soils. Plant Science. 269: 47-55.

Caverzan, A., Casassola, A., Brammer, S.P. (2016). Antioxidant responses of wheat plants under stress. Genetics and Molecular Biology. 39: 1-6.

Costache, M.A., Campeanu, G., Neata, G. (2012). Studies concerning the extraction of chlorophyll and total carotenoids from Vegetables. Romanian Biotechnological Letters. 17: 7702-7708.

Datta, J.K., Nag, S., Banerjee, A., Mondal, N.K. (2009). Impact of salt stress on five varieties of Wheat (Triticum aestivum L.) cultivars under laboratory condition. Journal of Applied Sciences and Environmental Management. 13 (3): 93-97.

F.A.O. (2013). Wheat in the world. Food corporate document repository. Agriculture and Consumer Protection.

Hayat, S., Hayat, Q., Alyemeni, M.N., Wani, A.S., Pichtel, J., Ahmad, A. (2012). Role of proline under changing environments: A review. Plant Signaling and Behavior. 1: 1456-1466.

Heath, R.L. and Packer, L. (1968). Photoperoxidation in isolated chloroplasts: II. Role of electron transfer. Archives of Biochemistry and Biophysics. 125(3): 850-857.

Hussain, T., Iqbal, A., Amir, I., Swati, Z.A. (2006). Chlorophyll-based screening for salinity tolerance in wheat genotypes. ARPN Journal of Agricultural and Biological Science. 8(8): 596-598.

Ibrahim, W., Ahmed, I.M., Chen, X., Wu, F. (2017). Genotype-dependent alleviation effects of exogenous GSH on salinity stress in cotton is related to improvement in chlorophyll content, photosynthetic performance and leaf/root ultrastructure. Environmental Science and Pollution Research. 24: 9417-9427.
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Jolliffe, I.T. (2002). Introduction. Springer New York. (pp. 1-9).

Jones, Jr. J.B. (1982). Hydroponics: its history and use in plant nutrition studies. Journal of Plant Nutrition. 5: 1003-1030.

Khalilq, A., Zia ul Haq, M., Ali, F., Aslam, F., Matloob, A., Navab, A., Hussain, S. (2015). Salinity tolerance in wheat cultivars is related to enhanced activities of enzymatic antioxidants and reduced lipid peroxidation. Clean-Soil, Air, Water. 43: 1248-1258.

Kumar, A., Lata, C., Krishnamurthy, S.L., Kumar, A., Prasad, K.R.K., Kulshreshtha, N. (2017). Physiological and biochemical characterization of rice varieties under salt and drought stresses. Journal of Soil Salinity and Water Quality. 9: 167-177.

Long, S.P. and Baker, N.R. (1986). Saline terrestrial environments. In: Photosynthesis in Contrasting Environments [N.R. Baker and S.P. Long, eds.] Elsevier, New York. 63-102.

Niu, L. and Liao, W. (2016). Hydrogen peroxide signaling in plant development and abiotic responses: crosstalk with nitric oxide and calcium. Frontiers in Plant Science. 4(7): 230. doi: 10.3389/fpls.2016.00230. eCollection 2016.

Petrov, V.D., Van, Breusegem, F. (2012). Hydrogen peroxide-a central hub for information flow in plant cells. AoB Plants.

Ramanjulu, S. and Sudhakar, C. (2001). Alleviation of NaCl salinity stress by calcium is partly related to the increased proline accumulation in mulberry (*Morus alba* L.) callus. Journal of Plant Biology. 28: 203-206.

Sairam, R.K., Srivastava, G.C., Agarwal, S., Meena, R.C. (2005). Differences in antioxidant activity in response to salinity stress in tolerant and susceptible wheat genotypes. Biologia Plantarum. 49: 85-91.

Szabados, L. and Savour’e, A. (2009). Proline, a multifunctional amino acid. Trends in Plant Science. 15: 89-97.

Velikova, V., Yordanov, I., Edreva, A., 2000. Oxidative Stress and Some Antioxidant Systems in Acid Rain-Treated Bean Plants: Protective Role of Exogenous Poly-amines. Plant Science. 151: 59-66.

Wang, M.C., Peng, Z.Y., Li, C.L., Li, F., Liu, C., Xia, G. (2008). Proteomic analysis on a high salt tolerance introgression strain of *Triticum aestivum/Thinopyrum ponticum*. Proteomics. 8: 1470-1489.

Wani, A. and Gupta, K.J. (2018). Reactive oxygen species, nitric oxide production and antioxidant gene expression during development of aerenchyma formation in wheat. Plant Signaling and Behavior. 1: 13(2).

Yildiz, M. and Terzi, H. (2013). Effect of NaCl Stress on Chlorophyll Biosynthesis, Proline, Lipid Peroxidation and Antioxidative Enzymes in Leaves of Salt-Tolerant and Salt-Sensitive Barley Cultivars. Journal of Agricultural Sciences. 19: 79-88.

Zhao, G.Q., Ma, B.L., Ren, C.Z. (2007). Growth, gas exchange, chlorophyll fluorescence and ion content of naked oat in response to salinity. Crop Science. 47: 123-131.

Zörb, C., Geißler, C.M., Dietz, K.J. (2019). Salinity and crop yield. Plant Biology. 21: 31-38.