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Response of grain sorghum to alpha-tochopherol and thiamine under salinity

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IN ORDER to evaluate the oxidative defense and growth of grain sorghum [*Sorghum bicolor (L.) Moench*] grown under salt stress (2500 and 5000 ppm than the tap water as a control) to application of alpha-tocopherol and thiamine (as antioxidants) a pot experiment was conduct in the greenhouse of the National Research Centre, Dokki, Cairo, Egypt**.** The obtained results showed that salinity decreased the dry weight of root, stem and whole plant and root more affected than stem and whole plant but leaves seemed to be without effect. On reverse, T/R ratio (top to root ratio) increased as the salinity level increased. This means that salinity affect the root more than any part of grain sorghum plants. It is clearly shown that different grain sorghum plants parts dry weight and their whole weight increased by tocopherol or tocopherol+thiamine (spraying on vegetative parts) in comparable with the control plants. On the opposite side, T/R decreased with tocopherol+thiamine only. This means that this treatment increased dry weight of root than the other part of sorghum plant. It is clearly shown from data that different grain sorghum plants parts dry weight increased by tocopherol or tocopherol+thiamine spraying in comparable with the control plants. On the opposite side, T/R decreased with tocopherol+thiamine only. This means that this treatment increased dry weight of root than the other part of sorghum plant. O2- and MDA (malondialdhiede) its concentrations negatively responded to alpha-tocopherol or alpha-tocopherol+thiamine. The depression in these parameters by alpha-tocopherol were: 52.07 and 30.08 and by alpha-tocopherol+thiamine were 59.50, and 38.52%, respectively compared to that of the control. On the other side, APX (ascorbate peroxidases), GR (glutathione reductase), PPO (polyphenole oxidases) and CAT (catalase) level increased by: 83.81, 53.50, 61.88 and 19.64 % as the grain sorghum plants sprayed by alpha-tocopherol and thiamine, respectively it is compare to the plants received distilled water. These Data lead to conclusion that application of alpha-tocopherol or thiamine increased tolerance of grain sorghum plants.

Keywords: Grain sorghum (*Sorghum bicolor L.*), Moench, Alpha, tocopherol, Thiamine, Salinity, Dry matter, Antioxidant enzymes.

Introduction

Salinity of soil is a global increasing problem and main obstacle to agricultural productivity especially Environmental stresses are considered the main factor affect adversely the world food production. There are over 800 million hectares of land worldwide are affected by salinity (**Munns, 2005**). Salt stress is a major abiotic stress and induce pig problem in arid and semi-arid regions and irrigation lands. It represents approximately 7% of the world's land area, 20% of the world's cultivated land, it affected nearly half of the irrigation and with high salt contents (**Rhoades and Loveday 1990 and Szabolcs 1994**). Salinity adversely affected growth and yield of different crops cultivated in these areas or irrigated by saline water especially in areas suffer from water shortage and the only available the saline water (**Hassanain and Azab, 1990; Hussein, et al 2008; Sairam and Srivastava, 2002; Hussein, et al 2012; Gondim, et al 2013 and Hussein, et al 2017)** in regions where irrigation is necessary (**Sagar, et al 2019).** Salinity is a major threat to plant growth, development, and overall plant productivity (**Hussein and Abu Bakr, 2018**). Additions of toxic salts in the water lower the osmotic potential of water that leads to water shortage and less absorption of water by roots and ultimately causes the development of osmotic stress. Osmotic stress results in the disturbance of physiological (**Khalil, et al 2012**) and biochemical response (**Hussein and Orabi, 2008)** of plants and adversely affect the plant development, yield, and production (**Huang, et al 2006; Hussein, et al 2008; Ashraf, et al 2013 and Kausar and Gull, 2018**).Different researches were done and revealed that salinity affected most the physiological and metabolic processes such as photosynthesis, water and mineral

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uptake, anatomical structure and oxidative defense (**Redondo-Gomez, et al 2007; Hussein, et al 2008; Hussein, et al 2011 and Orabi, et al 2018**). A number of defense compounds accumulated in plants such as ascorbate (vitamin C), glutathione, N- acetyl Cys, tocopherols (vitamin E), carotenoids, phenyl propanoids, polyamines, and indoles in response to abiotic stresses (I**riti and Faoro, 2007**). In Photosynthetic organisms, tocopherols are lipophilic antioxidants that are synthesized exclusively, while α-tocopherol accumulates predominantly in photosynthetic tissue, seeds are rich in γ-tocopherol. Recently, little is known about the specific roles of α- and γ-tocopherol in different plant tissues (**Abbasi, et al 2007).** The α-Tocopherol is the major vitamin E compound found in leaf chloroplasts, where it is located in the chloroplast envelope, thylakoid membranes and plastoglobul (**Munné-Bosch, 2005**).

Tocopherols deactivates photosynthesis-derived reactive oxygen species (mainly 1O2 and OH), and prevents the propagation of lipid peroxidation by scavenging lipid peroxyl radicals in thylakoid membranes. The level of α-Tocopherol, differentially Change in response to environmental constraints, and this process depending on the magnitude of the stress and species-sensitivity to stresses (**Munné-Bosch, 2005**). Thiamie pyrophosphate (TPP) involved in a number of important metabolic processes and is an essential cofactor required by enzyme. This metabolic processes such as the production of acetyl-CoA, the tricarboxylic acid cycle, the pentose phosphate pathway/Calvin cycle, branched chain amino acid biosynthesis, and isoprenoid biosynthesis (**Hohmann and Meacock, 1998**). While in vitro studies suggest that thiamin can directly act as an antioxidant, the association between oxidative stress and thiamin-dependent enzymes may also indicate a vital cofactor role for thiamin under stress conditions (**Tunc-Dzdemir, et al 2009**).

Wanti, et al (2013) reported that oxidative stress and eventual cell death in plants can be caused by excess H_2O_2 accumulation. Since stress factors provoke enhanced production of H_2O_2 in plants, severe damage to biomolecules can be possible due to elevated and non-metabolized cellular H_2O_2. H_2O_2-metabolizing enzymes endowed plants such as catalases (CAT), ascorbate peroxidases (APX), some peroxiredoxins, glutathione/thioredoxin peroxidases, and glutathione sulfo-transferases. However, CAT and APX are the most notably distinguished enzymes since the former mainly occurs in peroxisomes and does not require a reductant for catalyzing a dismutation reaction. In particular, APX has a higher affinity for H_2O_2 and reduces it to H_2O in chloroplasts, cytosol, mitochondria and peroxisomes, as well as in the apoplastic space, utilizing ascorbate as specific electron donor. On the other hand, APX, GR and PPO concentration increased by: 83.81, 53.50 and 81.88 % as the grain sorghum plants sprayed by alpha-tocopherol (plants received distilled water).

Sorghum (*Sorghum bicolor L. Moench*) is a moderately saline tolerant grain and forage crop, (**Tabatabaei and Anagholi, 2012**), can tolerate up to 8.6 dS m-1soil salinity (**Maas, et a1 986**). It is one of the five major cultivated species in the world having several economically important uses such as 55%as food, 33% as feed and others are as fuel, fibre, fermentation and fertilizer.

Moreover, the antioxidant and vitamins and its effect of amelioration of salt stress in plants were reported in several investigations (**Hussein and El-Greatly, 2007; Hussein, et al 2008; Ashraf, et al 2009; Hussein, et al 2011 and Bekheta and Hussein, 2014).**

Therefore, this work aimed to investigate the effect of alph-tochopherol and thiamine on growth and antioxidant enzymes of grain sorghum plants grown under salinity condition.

Materials and Methods

A pot experiment was carried out at the greenhouse of the National Research Center, Dokki, Egypt during the summer season of 2017. Seeds were provided from the Agricultural Research Center, Giza, Egypt and directly sown on the 1st of April in earthenware pots of 40 cm diameter filled with 15 kg of clay loam soil. Plants were thinned to two plants/pot at 10 days after sowing. The treatments were as follows:

Salinity treatments: irrigation by diluted sea water 2500 and 5000 ppm more than tap water as a control.

Antioxidants: Alpha-tocopherol (100 ppm) and tocopherol (100 ppm)+Thiamine (100 ppm) more than distilled water (as a control) were sprayed twice, the 1st was 21 days and the 2nd was applied two weeks later.

All pots received a recommended doses of N, P and K fertilizers, namely 6 g calcium super phosphate (15.5% P2O5), 1.5 g potassium sulphate (48.5% K2O) and 1.5 g ammonium nitrate (33.5% N), which was added immediately before sowing. Seeds of grain sorghum *(Sorghum bicolor (L.)* Moench) were regularly irrigated with tap water and saline water starting 21 days. The general principal stated by (**Boutraa and Sanders, 2001**) was used for the water treatments application. The three exogenous of antioxidants treatments and all possible combinations between them were tested. This experiment included 9 treatments which included all combinations between three salinity treatments and three exogenous antioxidants application. Treatments were arranged in a split plot design with six replicates each.

At 50 days from sowing the plants were sampled at random to estimate the following characters: fresh and dry weights (g) of root, stem, leaves and whole plant and for Biochemical measurements in leaves.

Enzymatic and non-enzymatic antioxidants measurements: Extraction of the antioxidant enzymes Ascorbate peroxidase (APX), catalase (CAT) and glutathione reductase (GR) were determined as 5g of frozen leaves tissues were homogenized in prechilled mortar in presence of 10 ml of 50 mM potassium phosphate buffer (pH7) with 1% (W/V) insoluble polyvinyl pyrolidone (PVP) and 0.1 mM EDTA. The extraction procedures were repeated twice and supernatants were pooled, raised to a certain volume, referred as crude enzyme extract, all operations were carried out at -4ºC for further analysis. The activity of APX (EC1.11.1.11) was determined according to (**Nakano and Asada, 1981).** One unit of APX was defined as the amount of enzyme that breaks down 1µ mol of ascorbate per min. and GR activity (EC 1.6.4.2) was determined according to (**Zanetti, 1979**). One unit of GR was defined as the amount of enzyme that decreases 1A340 per min. The activity of catalase (EC1.11.1.6) was determined according to the method of Aebi (1983) by the decrease of absorbance at 240 nm for 1 min as a consequence of H_2O_2 consumption. Poly phenole oxidase (PPO)(EC 1.10.3.1) was determined using the method of Oktay et al. (1995). Total phenolic compound contents were determined by the colourimetric method of folin-Denis as described by (**Daniel and George, 1972)**. A calibration curve of pyrogallol was prepared, and the results were expressed as mg Pyr. (Pyrogallol).

Oxidative damage measurements and scavenging: Determination of the generated superoxide radical (O2˙-) was base on the reduction of nitro blue tetrazolium (NBT) according to the method described by **(Doke, N.1983**). Lipid peroxidation was determine by measuring Malondialdehyde (MDA) content as described by **(Dhindsa, et al 1982**) Superoxide radical (O2˙-) scavenging activity was determined as described by (**Beauchamp and Fridovich**, **1971**) and modified by **(Ibrahim, et al 2013**). Ascorbic acid was use as a positive control compound.

The collected data were subject to the statistical analysis of variance using the normal (F) test and means were evaluated by using Least Significant Difference (LSD) test at the 5% level according to (**Snedecor and Cochran, 1980).**

Results and discussion

Fresh and dry matter

Salinity

Data in Table (1) showed that salinity decreased the dry weight of root, stem and whole plant and root more affected than stem and whole plant but leaves seemed to be without effect. On reverse, T/R ratio increased as the salinity level increased. This means that salinity affect the root more than any part of grain sorghum plants. Different researches has been done reported the adverse effect of salinity on different crops: **Hussein and Mandour (1979); Abd El-Rasoul, et al 1980); Nour, et al (1982); Ashoub, et al (1984); Mousa, et al(1987); Netonodo, et al (2004) Nimir, et al (2017) and Machad and Serralheiro (2017).**The study of **Sagar, et al (2019**) showed that salinity opposite to the regular growth of sorghum seedlings, as indicated by shoot and root length stress tolerance index. Consequently, the root-shoot ratio and total dry matter decreased with increasing salinity. These results are consistent **(Qu, et al (2012**) They found NaCl salinity led to be short of growth characters and the shoot was more affected than the root, while leaf indices was declined significantly measured up to the control plants. Reduction in growth may be caused by a reduced number of elongated cells and the reduced rate of cell elongation (**Sagar, 2017**) and these happen due to lower transport rate of essential ions like due to salinity that reduce the N compounds and increased Na n plant under high salinity (**Hamid, et al 2008**).

Concerning this phenomenon, salinity from the accumulation of salts in soil or irrigation by saline water and both affected the soil properties and plant metabolism. **Hassanain and Azab (1990)** noticed that the increasing of soil salinity levels significantly decreased dry weight of shoots and roots as well as root volume of the tested genotypes at seedling stage. **Hussein, et al (2017)** used diluted sea water on irrigation of jojoba and concluded that this depressed the in vegetative growth and dry matter of plants. The adverse effect of salinity may be attributed to the inhibition effect on photosynthetic apparatus and carbohydrates decreased which reflected on the dry matter accumulation (**Sudhir and. Murthy, 2004; Koyro, 2006 and Hussein et al 2015**), protein building depression (**Zagorchev, et al 2016**), enzymes activity (**Sozharajan and Natarajan, 2013**), disturbance in nutrients uptake, and distribution (**Munns and Taker, 2002**; **Hussein**, **et al 2008; Abd El-Halin, et al 2019 and Hussein, et al 2019**), effects on osmotic adjustment (**Alarcon, et al 1994** and **Neto, et al 2004**) and as in our study the effect on oxidative defense (**Orabi, et a l 2018; Hussein and Orabi, 2008** and **Abd Elgawad, et al 2016**). Salt stress causes decrease in plant growth and productivity by disrupting physiological processes, especially photosynthesis. The accumulation of sodium ions intracellular at salt condition changes the ratio of K :Na, which seems to affect the bioenergetic processes of photosynthesis (**Sudhar and Murthy, 2004**).

Table 1. Response of grain sorghum growth to salt stress.

Sal	**Fresh weight g**				**Dry weight g**				**T/R**
	Root	**Stem**	**Leaves.**	**Whole**	**Root**	**Stem**	**Leaves.**	**Whole**	
T.W	7.58	32.96	22.87	63.41	3.98	8.01	6.94	18.93	3.76
S1	4.60	26.69	19.77	51.06	2.29	5.38	7.11	14.78	5.45
S2	3.61	28.51	17.23	49.35	1.81	5.24	6.21	13.26	6.33
LSD	1.11	4.49	N.S	N.S	N.S	2.94	N.S	N.S	….

T.W=Tap water S1=2500 ppm S2=5000 ppm T/R= Top/ root ratio.

Oxidative stress and eventual cell death in plants can be caused by excess H_2O_2 accumulation. Since stress factors provoke enhanced production of H_2O_2 in plants, biomolecules severe damage can be possible due to elevated and non-metabolized cellular H_2O_2. Plant tissues are endowed with H_2O_2-metabolizing enzymes such as catalases (CAT), ascorbate peroxidases (APX), some peroxiredoxins, glutathione/thioredoxin peroxidases, and glutathione sulfo-transferases. **Netonodo, et al (2004**) mentioned that roots and stems accumulated substantial amounts of sodium, saturated at 150 mM external NaCL. K+, and Ca^{++} accumulation in the root stem and leaves was strongly inhibited and was minimally impaired but that of the stem and leaves was affected strongly. Sodium continuously accumulated in leaves which was preferentially deposited in the sheaths. Mature leaves contain more K^+ and Mg^+ ions than the young leaves.

Additionaly, salinity injury in plant growth may be due to the disturbance in mineral uptake and contents. **Anubha Sinha and Rana (1986)** noticed that there occurred an increase in the concentration of certain nutrients such as N, Ca, Mg, TNC in the plants in response to salinity, which along with increased root: shoot ratios was inferred as an adaptive feature of the plant for persistence under saline conditions. K concentration, K/Na and Ca/Na ratios decreased significantly, while Na concentration increased in root, shoot, and seed as the increase in soil salinity. In shoots, Pconcentration significantly decreased under salinity stress. Moreover, **Weisany, et al (2014**) stated that calcium significantly decreased in root, but increased in seed with increased salinization. **Munnus and Tester (2008**) concluded that salinity affects plants through osmotic stress and ion imbalance and toxicity. Salt-induced decrease in the Alpha-tocopherol and Thiamin soil water potential through osmotic effects. High salts inside the plant take time to accumulate before they affect plant function. A wide range of mechanisms have developed in plants to sustain productivity under salt stress environment. These mechanisms are osmotic adjustment, Na+ and/or Cl−exclusion, and tissue tolerance of high concentrations of Na+ and/or. Moreover, many researches on salt tolerance of various crops has indicated that salt tolerance largely depends on genera and species and even on cultivars within certain species (**Niu, et al 2012**). **Nimir, et al (2017)** indicated that Na+ content was gradually increased with salt increase. Stomatal conductance, photosynthetic rate, transpiration rate, and K+ content were significantly decreased due to high salt concentration. The medium salinity level of 2 g NaCl per kg dry soil decreased Ca^{2+}, P and Mg^{2+} content. **Hussein, et al (2015) on onion, Hussein, et al (2017) on jojoba and Hussein, et al (2008**) on grain sorghum, related the adverse effect of salinity to the disturbance on mineral absorption and distribution and also to the changes in anatomical structure of plant. They related this effects to the decrease in stomatal closer, Co_2 exchange and photosynthesis activity. This bade effect may be due to the unbalance in growth regulators. While **Hussein and Oraby (2008) and Abd El-Baky, et al 2014)** attributed this negative effects on growth and yield of plants to the depression antioxidant activity in to the depression on antioxidant defense. **Sairam, et** al **(2005**) indicated that salinity stress decreased relative water content (RWC) and membrane stability index (MSI) that was confirmed by **Semida, et al (2015).** The application of αTOC, particularly at 0.50 mM significantly increased RWC and MSI, maintaining cells turgid for healthy metabolic processes and membrane integrity.

Table 2. Response of grain sorghum plants growth to alpha-tocopherol and thiamine.

Antiox.	**Freh weight g**				**Dry weight g**				**T/R**
	Root	**Stem**	**Leaves.**	**Whole**	**Root**	**Stem**	**Leaves.**	**Whole**	
Dw	3.55	20.35	14.61	38.51	1.91	4.66	5.62	12.19	5.38
Toc	5.11	29.33	18.10	52.45	2.47	6.80	6.50	15.77	5.39
To.+Th.	6.23	39.40	27.18	72.81	3.71	7.87	7.47	19.07	4.14
LSD	1.05	4.99	5.52	3.88	1.81	N.S	4.19	5.44	….

Dw= Distilled water Toc=alpha tochopherol Thi=Thiamine T/R= Top/ root ratio.

It is clearly shown from Data in Table (2) that different grain sorghum plants parts dry weight and their whole weight increased by tochopherol or tochopherol + thiamine spraying in comparable with the control plants. On the opposite side, T/R decreased with tochopherol+ thiamine only. This means that this treatment increased dry weight of root than the other part of sorghum plant.

Tocopherol enhance growth and yield through its effect on growth regulators as found by **El-Hariri, et al (2012)** who noticed an increase in IAA content in flax plants by the foliar application of αTOC, and attributed this increased IAA to the role of αTOC in activating the biosynthesis of endogenous hormone, reflecting in stimulating cell division and/or the cell enlargement**. Barkat, et al 2003, Hussein and Orabi (2008) and Abdel-Baky, et al (2008). Hussein, et al 2007 and Simadi, et al (2014)** reported that all enhanced parameters (i.e., growth traits, plant water relations, contents of nutrients and their relations, and final yields) by the foliar application of αTOC which were accompanied with the improved stem and leaf anatomy. This gave an opportunity to a good translocation of the absorbed nutrients into healthy cells to be used in different metabolic processes positively reflecting in vigorous growth and satisfactory yield under the adverse conditions of the tested newly-reclaimed saline soil. **Sayed and Gaballah (2002)** found that root or shoot application of thiamine reduced membrane injury by either heat or dehydration stress, lowered leaf ψw, improved uptake of K+ and increased leaf RWC, Chl, SS, TAA contents and dry mass production. However, in vitro studies of **Hu, et al (1995) Jung and Kim (2003)** showed that thiamine is a potent scavenger of hydroxyl radicals and superoxide and could protect membranes from lipid peroxidation. **Lukienko et al (2000**) and our results in this work confirming these findings. **Gadallah (2002)** found that thiamine-induced reduced membrane injury and increased leaf RWC. Excess lipid oxidation will eventually result in membrane damage. **Kaya, et al (2014)** reported that exogenously applied thiamine induced growth improvement in maize plants was found to be associated with reduced membrane permeability, MDA and H_2O_2 levels, and altered activities of some key antioxidant enzymes such as CAT, SOD and POD as well as increased photosynthetic pigment concentration under saline regime.

Interaction

Tocopherol deactivates photosynthesis-derived reactive oxygen species (mainly O_2 and OH), and prevents the propagation of lipid peroxidation by scavenging lipid peroxyl radicals in thylakoid membranes. α-Tocopherol levels change differentially in response to environmental constraints, depending on the magnitude of the stress and species-sensitivity to stress (**Munné-Bosch, 2005**).

Table 3. Response of grain sorghum plants growth to alpha-tocopherol and thiamin and salt stress.

Sal	Antiox.	Fresh weight g				Dry weight g				T/R
		Root	Stem	Leaves.	Whole	Root	Stem	Leaves.	Whole	
T.W	Dw	5.88	23.43	16.41	40.42	2.62	5.64	5.18	12.94	7.41
	Toc	7.01	35.72	20.30	36.66	2.84	7.73	6.40	17.27	6.08
	Toc.+Thi	9.85	39.73	31.91	81.49	6.27	10.67	9.23	26.13	8.71
S1	Dw	4.43	16.92	13.77	35.02	1.63	3.25	6.80	11.68	6.18
	Toc	4.87	28.11	17.62	50.60	2.52	5.21	7.50	15.23	6.05
	Toc.+Thi	4.50	38.05	27.93	66.43	2.73	7.69	7.04	17.46	5.40
S2	Dw	3.03	20.71	13.65	37.93	1.29	5.09	4.88	9.36	5.48
	Toc	3.44	24.15	16.36	43.95	2.04	7.45	5.61	12.74	5.25
	Toc.+Thi	4.35	40.67	21.69	55.71	2.11	5.24	8.13	17.69	7.38
LSD		1.81	4.49	N.S	6.71	1.51	N.S	N.S	N.S	…..

T.W=Tap water S1=2500 ppm S2=5000 ppm Dw= Distilled water Toc=alpha tochopherol Thi=Thiamine T/R= Top/ root ratio.

Examination of Data in Table (2) showed that generally antioxidant substances improved the fresh and dry matter of grain sorghum plants grown under salinity or fresh water irrigation. Moreover, application of tochopherol plus thiamine gave the highest values of root as well as whole plant dry matter. This was true under both fresh water or salinity treatments. In addition, it was observed that the combined of thiamine+tochopherole more effective under fresh water than salinity treatments. **Semida, et al (2014)** found thatαTOC-treated plants, grown under the abovementioned adverse conditions, had enhanced all growth parameters (i.e., shoot length and numbers).In addition, performance index, relative water content, membrane stability index, nutrients and their relations, and anatomy of stem and leaf were significantly improved in αTOC-treated plants compared to control plants of leaves and branches, leaf area, and shoot fresh and dry weights) and yield and its components (i.e., number of dry pod per plant, average 100-seed weight, and dry seed yield per plant and per hectare) of both varieties compared to control plants. **Hariri, et al. (2010)** found an increase in IAA content in flax plants by the foliar application of αTOC, and attributed this increased IAA to the role of αTOC in activating the biosynthesis of endogenous hormone, reflecting in stimulating cell division and/or the cell enlargement that lead to the improvement in plant growth under stress. The same authors proved an increase in total phenols by αTOC application, which play a mechanism in regulation of plant metabolic processes, act as a substrate for many antioxidant enzymes. **Sayed and Gadallah (2000)** mentioned that the effects of salinity (ψs), thiamin (Thi.) and their interaction (ψs × Thi) on the parameters tested were significant. Salinity was dominant (as indicated by η2 values) in affecting the contents of Ca^{2+}, Cl^{-}, TAA and membrane estability to heat and leaf ψw. The role of thiamin was dominant for Na+, K+ and SS contents and the contribution of interaction was dominant for growth parameters, Chl. and root ψw.

Salt stress markedly suppressed shoot and root dry mass, total chlorophylls (―a‖ + ―b‖), leaf water potential and maximum fluorescence yield (Fv/Fm) in the plants of both maize cultivars, but it increased proline accumulation, leaf osmotic pressure, malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) concentrations, electrolyte leakage (EL) as well as activities of some key antioxidant enzymes, superoxide dismutase (SOD; EC. 1.15.1.1), peroxidase (POD; EC. 1.11.1.7) and catalase (CAT; EC. 1.11.1.6). Salt-induced reduction in plant growth parameters was higher in the salt-sensitive cultivar, Apex 836, which was found to be associated with relatively increased EL, and MDA and H_2O_2 levels, and decreased activities of the key antioxidant enzymes (**Kaya, et al. 2015**).

affects both plant growth and productivity by causing high production of reactive oxygen species (ROS) such as hydrogen peroxide (H_2O_2), superoxide and hydroxyl radical (**Mittler**, **2002**). All these substances being very reactive are harmful to vital cellular macromolecules such as proteins and lipids (**Noctor et al 2014**). However, to counteract ROS, plants can upregulate their antioxidative defense mechanism by stimulating the activities of key antioxidative enzymes including superoxide dismutases (SOD), catalases (CAT) and peroxidases (POX) (**Sai-Kachout et al 2013).** The salt stress is known to cause reduction in cell division and elongation (**Pitann et al 2009**) which is mainly due to salt induced alterations in the nutrient uptake, induced formation of reactive oxygen species (Ashraf, 2009), inhibition of cytoplasmic enzymes, turgor loss (**Pitann et al 2009)** and hormonal imbalance (**Ashraf et al 2010**) which will naturally impair plant growth and finally the yield.

found that he single TOC foliar application recorded the positive results significantly improved soil physical and chemical properties, which positively reflected on plant growth and productivity, physio-biochemical attributes, mineral nutrients (N, P, K and Ca), osmo-protectants (soluble sugars and proline), non-enzymatic (ascorbic acid, glutathione and TOC) and enzymatic (superoxide dismutase, catalase and guaiacol peroxidase (GPOX)) antioxidants compared to untreated controls. Integrated KH + TOC treatment was most effective compared to the single treatments. The above results recommended benefits of this integrated KH + TOC for the possibility of sustainable agronomic performance of common beans grown on saline soils.

Anti-Oxidative system

Salinity

As the Data in Table (4) showed, salinity induced increases in O_{2-} and MDA in leaves tissues of grain sorghum plants as compared to the control **Kaya, et al (2015)** noticed that salinity increased malondialdehyde (MDA) i.e. lipid peroxidation and H_2O_2 in maize cultivars. On the opposite side, APX, GR, CAT and PPO activity increased parallel to the increase in salinity level up to the highest level used in comparable with plants irrigated by fresh water.

.Soil salinity adversely

Table 4. Anti-Oxidative system as affected under salinity condition.

Sal	O_2- A680/ g FW	MDA µmole/g FW	Phenols mg/g FW	O_2-scavinging activity %	APX µmole/ g FW	GR µmole/g FW	PPO µmole/g FW	CAT µmole/g FW
Tw	0.32	7.71	2.51	76.29	2.76	3.9374	21.12	88.37
S1	0.84	9.64	3.86	84.52	4.25	4.9571	23.47	98.75
S2	1.18	12.50	4.84	83.96	5.02	5.9770	26.36	109.58
LSD	0.03	0.73	0.72	0.80	0.68	1.102	1.678	1.52

T.W=Tap water S1=2500 ppm S2=5000 ppm Apx= Ascorbate peroxidase GR= Glutathione reductase PPO=Poly phenol oxidase CAT= Catalase

Soil salinity adversely affects both plant growth and productivity by causing high production of reactive oxygen species (ROS) such as hydrogen peroxide (H_2O_2), superoxide and hydroxyl radical **(Mittler 2002).** All these substances being very reactive are harmful to vital cellular macromolecules such as proteins and lipids **(Noctor et al 2014).** However, to counteract ROS, plants can upregulate their antioxidative defense mechanism by stimulating the activities of key antioxidative enzymes including superoxide dismutases (SOD), catalases (CAT) and peroxidases (POX (**Sai-Kachout et al 2013). Kaya, et al (2015)** reported that salinity increased the activity of key antioxidant enzymes, SOD, POD and CAT in plants of maize cultivars. **Wani, et al (2013)** mentioned that salinity induced modulation in antioxidant system.

Oxidative stress and eventual cell death in plants can be caused by excess H_2O_2 accumulation. Since stress factors provoke enhanced production of H_2O_2 in plants, severe damage to biomolecules can be possible due to elevated and non-metabolized cellular H_2O_2. Plants are endowed with H_2O_{2-} metabolizing enzymes such as catalases (CAT), ascorbate peroxidases (APX), some peroxiredoxins, glutathione/thioredoxin peroxidases, and glutathione sulfo-transferases. However, the most notably distinguished enzymes are CAT and APX since the former mainly occurs in peroxisomes and does not require a reductant for catalyzing a dismutation reaction. In particular, APX has a higher affinity for H_2O_2 and reduces it to H_2O in chloroplasts, cytosol, mitochondria and peroxisomes, as well as in the apoplastic space, utilizing ascorbate as specific electron donor. Based on recent reports, hiamin biosynthetic enzymes (**Sofo, et al 2015**). Based on recent reports, the data revealed that the antioxidant enzyme activity [catalase (CAT), peroxidase (POX) and superoxide dismutase (SOD) increased in response to the concentrations of NaCl in the soil in both the varieties [catalase (CAT), peroxidase (POX) and superoxide dismutase (SOD)].

Alpha-tochopherols and thiamine

Data presented in Table (5) showed that O_{2-} and MDA lts concentrations negatively responded to alpha-tocopherol or alpha-tocopherol+thiamine. The depression in these parameters by alpha-tocopherol were: 52.07 and 30.08 and by alpha-tocopherol+thiamine were 59.50, and 38.52%, respectively compared to that of the control. The effects of this compound in intracellular signaling may be either direct, by interacting with key components of the signaling cascade, or indirect, through the prevention of lipid peroxidation or the scavenging of singlet oxygen. In the latter case, α-tocopherol may regulate the concentration of reactive oxygen species and plant hormones, such as jasmonic acid, within the cell, which control both the growth and development of plants, and also plant response to stress (**Munné- Bosch, and Alegre, 2002**).

Table 5. Anti-Oxidative system as affected with alphatocopherol and thiamine spraying.

Sal	O2- A680/g FW	MDA µmole/g FW	Phenols mg/g FW	O2-scavin -ging activity %	APX µmole/g FW	GR µmole/g FW	PPO µmole/ g FW	CAT µmole/g FW
Dw	1.21	12.90	2.79	78.52	2.78	3.8549	17.60	88.45
Toc	0.58	9.02	3.81	81.57	4.15	5.0986	24.86	101.81
Toc.+Thi	0.49	7.93	4.61	84.67	5.11	5.9173	28.49	105.82
LSD	0.05	0.66	0.98	0.52	0.181	0.261	N.S.	2.48

Dw= Distilled water Toc=alpha tochopherol Thi=Thiamine Apx= Ascorbate peroxidase GR= Glutathione reductase PPO=Poly phenol oxidase CAT= Catalase

On the other side, APX, GR, PPO and CAT level increased by: 83.81, 53.50, 61.88 and 19.64 % as the grain sorghum plants sprayed by alpha-tocopherol and thiamine, respectively if it is compared to the plants received distilled water. **Hemada, et al (2017**) found that the single TOC foliar application recorded effects on enzymatic (superoxide dismutase, catalase and guaiacol peroxidase (GPOX)) and antioxidants compared to untreated controls.

Tunc-Dzdemir, et al (2009) pointed out that the accumulation of these compounds (thiamin or thiamin pyrophosphate) in plants subjected to oxidative stress was accompanied by enhanced expression of transcripts encoding t). Oxidative stress and eventual cell death in plants can be caused by excess H_2O_2 accumulation. Since stress factors provoke enhanced production of H_2O_2 in plants, severe damage to biomolecules can be possible due to elevated and non-metabolized cellular H_2O_2. Plants are endowed with H_2O_2-metabolizing enzymes such as catalases (CAT), ascorbate peroxidases (APX), some peroxiredoxins, glutathione/thioredoxin peroxidases, and glutathione sulfo-transferases. However, the most notably distinguished enzymes are CAT and APX since the former mainly occurs in peroxisomes and does not require a reductant for catalyzing a dismutation reaction. In particular, APX has a higher affinity for H_2O_2 and reduces it to H_2O in chloroplasts, cytosol, mitochondria and peroxisomes, as well as in the apoplastic space, utilizing ascorbate as specific electron donor.Based on recent reports, thiamine biosynthetic enzymes (**Sofo, et al 2015**). The effects of this compound in intracellular signaling may be either direct, by interacting with key components of the signaling cascade, or indirect, through the prevention of lipid peroxidation or the scavenging of singlet oxygen. In the latter case, α-tocopherol may regulate the concentration of reactive oxygen species and plant hormones, such as jasmonic acid, within the cell, which control both the growth and development of plants, and also plant response to stress (**Munné-Bosch, and Alegre, 2002).**

Interaction

The interaction between salinity and vitamins on APX, GR, PPO and CAT were illustrated in Table (6). Alpha-tocopherol alone decreased MDA as well as O_{2-} by both salinity treatments but under the second level of salinity was more than that under the first treatment of salts. Nevertheless, the increment % in total phenols was more with the 1st level of salt stress than that resulted under the second level of salt stress.

Recent studies indicate that compensatory mechanisms exist to afford adequate protection to the photosynthetic apparatus in the absence of alpha- tocopherol, and provide further evidence that it is the whole set of antioxidant defenses (ascorbate, glutathione, carotenoids, tocopherols and other isoprenoids, flavonoids and enzymatic antioxidants) rather than a single antioxidant, which helps plants to withstand environmental stress (**Munne-Bosch, 2005**). Regarding the effect of this interaction on enzymes activity, tocopherol solitary increased pronouncedly GR activity in green leaves of grain sorghum, however PPO activity did not affect by the moderate salt stress and markedly increased by the highest salt stress used more than that in plants received of water in irrigation contains 275 ppm (Tap water) salts only (Table 6). Under normal conditions, ROS are generated at very low levels and a homeostasis is maintained between production and quenching of these molecules. This balance could be disturbed by the environmental stress, giving rise to a rapid increase in intercellular ROS levels which induce oxidative damage to lipids, proteins, and/or nucleic acids. In order to cope with the oxidative damages under stress, plants raise the level of endogenous enzymes (CAT, POX and SOD) and the non-enzymatic component such as proline (**Sharma, et al 2010**).

This Data showed that all the O_{2-} as well as MDA decreased with mixed alpha-tocopherol and thiamine under both salinity levels, but the decrement in the1st level of salinity is more than that caused by the second level, these decrement percentages in the case of the two damage criteria be less than the control while the reverse was true for phenol which still more than the control. Concerning the interaction effect of tocopherol and thiamine and salt stress are presented in the same Table. This Data also showed that both vitamins decreased the level of the O_2- as well as MDA. On reverse total phenols markedly increased continuously which its percentage of increment under the second level of salinity approach to be the 2 folds of those induced under fresh water of irrigation.

High salinity causes ion toxicity and osmotic stress, leading to the excessive production of reactive oxygen species (ROS) in plant cells, including superoxide radicals, hydrogen peroxide, hydroxyl anions, and singlet oxygen. These ROS cause damage to lipids, proteins and DNA (**Yasar, et al 2006**). Also, the authors suggested that a-tocopherol application could effectively plants from salt stress damage presumably by quenching the excessive reactive oxygen species to protect the photosynthetic pigments and by enhancing osmotic adjustment (**Ye, et al 2017**).

Application of thiamine as seed soaking or foliar spray partly mitigated the deleterious effects of salinity on plants of both maize cultivars. The most promising effect of Thiamin on alleviation of adverse effects of salt stress on maize plants was found when it was applied as foliar spray at 100 mg l−1. Thiamin application considerably reduced tissue Na+ concentration, but improved those of N, P, Ca^{2+} and K^+ in the salt-stressed maize plants. Exogenously applied thiamin-induced growth improvement in maize plants was found to be associated with reduced membrane permeability, MDA and H_2O_2 levels, and altered activities of some key antioxidant enzymes such as CAT, SOD and POD as well as increased photosynthetic pigment concentration under saline regime. Exogenous application of thiamin promotes growth and antioxidative defense system at initial phases of development in salt-stressed plants of two maize cultivars differing in salinity tolerance (**Kaya, et al. 2015**).

Table 6. Anti-Oxidative system as affected with alpha-tocopherol and thiamin spraying and salt stress.

Sal	Antiox.	O_2- A680/ gFW	MDA µmole/ g FW	Phenols mg/g FW	O_2- scavinging activity%	APX µmole/g FW	GR µmole/g FW	PPO µmole /g FW	CAT µmole/ g FW
Tw	Dw	0.44	8.17	2.06	73.82	2.05	3.2154	16.00	83.14
	Toc	0.28	7.87	2.46	76.30	2,73	3.95.23	17.92	87.95
	Toc.+Thi	0.23	7.10	3.02	78.76	3.51	46445	18.88	90.97
S1	Dw	1.32	12.39	2.83	80.42	2.63	3.8630	21.44	88.88
	Toc	0.69	8.78	4.09	85.43	4.19	4.7785	24.96	102.26
	Toc.+Thi	0.52	7.74	4.66	87.70	5.92	6.2298	28.16	105.12
S2	Dw	1.87	18.15	3.48	81.33	3.65	4.4882	25.92	93.33
	Toc	0.94	10.41	4.89	82.99	5.52	6.5651	27.52	114.04
	Toc.+Thi	0.73	8.95	6.15	87.56	5.89	6.8777	32.04	121.37
LSD		0.08	1.15	1.30	0.90	0.314	0.454	N.S.	N.S

T.W.=Tap water S1=2500 ppm S2=5000 ppm Dw= Distilled water Toc=alpha tochopherol Thi=Thiamine Apx= Ascorbate peroxidase GR= Glutathione reductase PPO=Poly phenol oxidase CAT= Catalase.

In spite of the increases in APX, PPO, GR and CAT values (as a self produced plant defense against stress), the application of tocopherol or tocopherol combined with thiamine increased the activity of these enzymes. The addition of thiamine with tocopherol increased the effect of tocopherol on enzymes activity under moderate salinity or control treatment but under high saline treatment used the difference caused by tocopherol or addition of thiamine in these activities (except for PPO or CAT) seemed to be equal. However, under moderate salinity treatment CAT activity approximately equal either by tocopherol solitary or combined with thiamine. It is clear from Data in Table (6) that salinity increased O_{2-} and on reverse the treatments with tocopherol or tocopherol+ thiamine decreased it. Addition of thiamin with tocopherol enhancing the role of tocopherol in this phenomenon. Also, Data showed that, in spite of the increases in O_{2-} scavenging, the application of vitamin and nitrogen basic increased the scavenging activity.

When supplemented with exogenous thiamin, wild-type plants displayed enhanced tolerance to oxidative stress induced by paraquat. Thiamin application was also found to protect the reactive oxygen species-sensitive ascorbate peroxidase1 mutant from oxidative stress. Thiamin-induced tolerance to oxidative stress was accompanied by decreased production of reactive oxygen species in plants, as evidenced from decreased protein carbonylation and hydrogen peroxide accumulation. Because thiamin could protect the salicylic acid induction-deficient1 mutant against oxidative stress, thiamin-induced oxidative protection is likely independent of salicylic acid signaling or accumulation (**Tunc-Dzdemir, et al 2002**).

Application of antioxidants including vitamins has gained considerable attention for alleviating the adverse impact of moisture and salinity stress on plants. This can show in terms of plant growth and yield quantity and quality. They concluded that Vitamins could be regarded as natural and safety bio-regulators; low concentrations can exert considerable effects on different chemical activities (**Sadak and Dawood, 2014). Falk and Munne- Bosch (2010)** stated that tocopherols have been found to have a role in protection of thylakoids or other purified membranes from oxidative stress. The discovery of the function, for instance, of alpha- tocopherols in protecting photosystem II from singlet oxygen using this approach (**Kruk, et al 2005**). In the recent studies **(Hincha, 2008**) about the protective role of tocopherols in photosynthetic membranes are remarkable.

Our obtainable results with respect to antioxidant enzymes activity were in line with many scientists, antioxidant enzymes (CAT, SOD, and POD) are considered the most effective biomolecules in preventing cellular damage Ashraf, 2009. In his study. the activities of CAT, SOD, and POD were enhanced reasonably in the green pods of both mung bean cultivars under water stress. Likewise, in an earlier study with oilseed rape (Brassica napus L.), Abedi and **Pakniyat (2010)** reported a significant stimulation in the activities of SOD and POD enzymes, and a decrease in the activity of CAT enzyme under water-deficit stress. Similarly, an increase in the activities of CAT, GPX, and SOD enzymes was observed in chickpea plants grown under dryland conditions **(Mohammadi, et al 2011).** However, exogenously applied α-Toc significantly improved the activities of CAT, SOD and POD in the green pods of both mung bean cultivars. In a comprehensive review by **Szarka et al (2012),** it has been reported that stress-induced ROS accumulationis controlled by antioxidants (enzymatic and non enzymatic) including α-Toc. They are usually capable of chelating metal ions, eliminating their catalytic activity to form excessive ROS. No reports on the role of exogenous application of α-Toc on the antioxidative defense system of plants grown under stress conditions are available in the literature. However, it could be concluded that α-Toc supplementation could compensate for the harmful effects of stress-induced ROS through its powerful antioxidant properties (Bughdadi, 2013) but recent reports were mentioned by Orabi et al, (2014, 2017, 2018) and Orabi and Abdelhamid, (2016) using α-Toc on thyme, cucumber, mango and faba baen plants respectively in respect to tolerance enhancement via elevation of the antioxidative defense system.

Increase in tocopherol content around the second day under both stresses did not correlate with the chlorophyll degradation while such correlation was observed from the fifth day of severe stress. The activities of GSH-Px and GST as well as TBARS content showed NaCl-induced enhancement which was dose- and time-dependent. However, chloroplastic SOD was rather not involved in the response of tomato plants to NaCl stress. under the moderate stress similarly as in the early phase of severe stress tocopherol functions as a typical antioxidant, while in the late phase of the latter it may be involved in senescence signaling pathway and enables the recovery and recycling of the compounds significant for a plant organism (**Sklodowska, et al 2009**).

Biochemical and molecular features of the antioxidant enzymes superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX) play crucial roles in scavenging ROS in the different cell compartments and in response to stress conditions (**Racchi, 2013, Mansour, et al 2021 and Zhung, et al 2021).** Among the non enzymatic defenses, particular attention is paid to ascorbic acid, glutathione, flavonoids, carotenoids, and tocopherols. The operation of ROS scavenging systems during the seasonal cycle and specific developmental events, such as fruit ripening and senescence, are discussed in relation to the intense ROS formation during these processes that impact fruit quality. Particular attention is paid to Prunus (**Racchi, 2013**) and Citrus species because of the nutritional and antioxidant properties contained in these commonly consumed fruits.

Tocopherols and tocotrienols scavenge lipid peroxy radicals, thereby preventing the propagation of lipid peroxidation in membranes, and the ensuing products tocopheroxyl and tocotrienoxyl radicals, respectively, are recycled back to tocopherols and tocotrienols by the concerted action of other antioxidants. Furthermore, tocopherols and tocotrienols protect lipids and other membrane components by physically quenching and reacting chemically with singlet oxygen. The scavenging of singlet oxygen by α-tocopherol in chloroplasts results in the formation of, among other products, α - tocopherol quinone, a known contributor to cyclic electron transport in thylakoid membranes, therefore providing photo protection for chloroplasts. Moreover, given that α-tocopherol increases membrane rigidity, its concentration, together with that of the other membrane components, might be regulated to afford adequate fluidity for membrane function. Furthermore, α-tocopherol may affect intracellular signaling in plant cells. The effects of this compound in intracellular signaling may be either direct, by interacting with key components of the signaling cascade, or indirect, through the prevention of lipid peroxidation or the scavenging of singlet oxygen. In the latter case, α-tocopherol may regulate the concentration of reactive oxygen species and plant hormones, such as jasmonic acid, within the cell, which control both the growth and development of plants, and also plant response to stress (**Munné-Bosch and Alegre, 2002).**

Conclusion

Salinity is one of the main challenges face the productivity of agriculture and intern food through its bad effects on soil and plants. Our work designed to investigate the effect of some chemicals on growth and antioxidant activity of grain sorghum plants. Results showed that salinity adverse affected growth and increased free radicals and decreased the anti-oxidative system. Generally, the reverse was true for antioxidants application. This led us to conclude that both alpha tocopherols and thiamine enhanced oxidative defense and helped grain sorghum plants to tolerate salinity stress.

References

Abd El_Halim, S.; Hussein, M.M.; Talaab, A. and Seam, H. (2019). Growth and mineral status of cotton plants as affected by absicisic aced and salt stress. Intr. J. Eng. Tech. and Man. Res., 6 Issue 5: 142-152.

Abdel Rasoul; M.; Hussein M.M. and Ashoub, M.A. (1980). Effect of some growth regulators on the concentration of organic and amino acids in maize seedling under different levels of salinity 1- The concentration of organic acids. Ain Shams, Agric. Res. Bull., l No.1330. Aug

Abedi, T. and, Pakniyat, H. (2010). Antioxidant enzyme changes in response to drought stress in ten cultivars of oilseed rape (*Brassica napus L.*). Czech J. Genet Plant Breed., 46: 27-34.

Abbasi, A.; Hajirezaei, M.; Hofius, D; Sonnewald, U. and Voll, L.M. (2007). Specific Roles of α- and γ-Tocopherol in Abiotic Stress Responses of Transgenic Tobacco1,[W][OA]. Plant Physiol. 2007 Apr; 143(4): 1720–1738.

Abd El-Baky, H.H.; Hussein, M.M. and Baroty, G.S. (2008). Algal extraction improve antioxidants defense Abilities and salt tolerance of wheat plant irrigated with sea water. African J. of Biochemistry Res., 2(7):151-164.

Abd El Baky; H.H.; Hussein, M.M. and El-Baroty, G.S. (2014). (AJABS). Induces of antioxidant compounds and salt tolerance in wheat plants irrigated with sea water as application of microalgae spray. American Journal of Agricultural and Biological Sciences, 9 (2): 127-137.

Abd El-Baky, H.H.; Hussein, M.M.; El-Barouty, G.A., Ibrahim, E.A. and Sawsan, Y. El-Faham (2014). *Moringa stenopetalal* leaves extracts improve antioxidant defense abilities and salt tolerance of wheat plant irrigated with seawater. The J. of Agric. And Natural Resources Sci., 1 (1): 1-17.

Abdelgawad, H.; Zinta, G.; Hegab, M.M.; Pandey, R.; Asard, H. and Abuelsoud, W. (2016). High Salinity Induces Different Oxidative Stress and Antioxidant Responses in Maize Seedlings Organs. Front Plant Sci., 7: 276.

Aebi HE. 1983. Catalase. In: Methods of Enzymatic Analysis, Bergmeyer, H.U. (Ed.). Verlag Chemie, Weinhem, pp: 273-286.

Ahmad, P. and Sharma, S. (2010). Physio-biochemical attributes in two cultivars of mulberry (M. alba) under NaHCO3 stress. Int. J. Plant Prod., 4: 79-86.

Ahmadi, F.I.; Karimi, K. and Struik, P.C. (2018). Effect of exogenous application of methyl jasmonate on physiological and biochemical characteristics of *Brassica nupus L. cv, Talaye* under salinity stress. South Africa J. of Botany, 115: 5-11

Akram, N.A. and Ashraf, M. (2011). Pattern of accumulation of inorganic elements in sunflower (*Helianthus annuus L*) plants subjected to salt stress and exogenous application of 5-aminolevulinic acid. Pakistan J. Bot., 43 (2011), pp. 521-530.

Alarcón, J.J.; Sanchez-Blanco, M.J.; Bolarin, M.C. and Torrecillas, A. (1994). Growth and osmotic adjustment of two tomato cultivars during and after saline stress. Plant Soil 6: 75-82.

Ashoub, M.A.; Abdel Rasoul, M. and Hussein. M.M. (1984).. Effect of some growth regulators on the concentration of organic and amino acids in maize seedling under different levels of salinity. Ain Shams, Agric. Res. Bull., 29 (1): 257- 268.

Ashraf, M. (2009). Biotechnological approach of improving plant salt tolerance using antioxidants as markers. Biotechnol. Adv., 27: 84-93.

Ashraf, N.A.; Ashraf, M and Ali, Q. (2010). Response of two genetically diverse wheat cultivars to salt stress at different growth stages: leaf lipid peroxidation and phenolic contents. Pakistan J. Bot., 42: 559-566.

Ashraf, M.Y.; Rafique, N.; Ashraf, M.; Azhar, N. and Marchand, M. (2013). Effect of supplemental potassium (K+) on growth, physiological and biochemical attributes of wheat grown under saline conditions. J. Plant Nutr., 36:443–58.

Azooz, M.M.; A.M. Hassanein, A.M.; F.A.; Faheed, F.A. (2002). Riboflavin (vitamin B2) treatments counteract the adverse effects of salinity on growth and some relevant physiological responses of Hibiscus sabdariffa L. seedlings. Bulletin of the Faculty of Science, .Assuit University, 31: 395-403.

Bakheta, M.A. and Hussein, M.M. (2014). Uniconazole effect on endogenous hormones, proteins and proline contents of barley plants (*Hordium vulgare*) under salinity stress(Nacl). Bioscience J., 6(1): 39-44.

Barakat, H.B. (2003). Interactive effects of salinity and certain vitamin on gene expression and cell division.International Journal of Agriculture and Biology, 3: 219-228.

Beauchamp, C. and Fridovich, I. (1971). Superoxide dismutase: improved assays and an assay applicable to acrylamide gels. Analytical Biochem., 44: 276-278.

Boutraa, A. and Sanders, F.E. (2001). Influence of water stress on grain yield and vegetative growth of two cultivars of bean (*Phaseolus vulgaris L.).* Journal of Agronomy and Crop Science, 186: 229-237.

Bughdadi, F.A. (2013). Protective effects of vitamin E against motor nerve conduction deficit in diabetic rats. World Appl. Sci. J., 27: 28-32.

Daniel, H.D. and George, C.M. (1972). Peach seed dormancy in relation to indogenous inhibition and applied growth substances. J. of American society of horticulture science, 97:651-654.

Dhindsa, R.S.; Plumb-Dhindsa, P.L. Reid, D.M. (1982). Leaf senescence and lipid peroxidation effects of some phyto-hormones and scavengers of free radicals and singlet oxygen. Physiol. Plant, 56: 453-457.

Doke, N. (1983). Involvement of superoxide generation in the hypersensitive response of potato tuber tissues to infection with an incompatible race of phytophthora infestance and to hyphal wall components. Physiol. Plant Pathol., 23: 345-35.

Falk, J. and Munne-Bosch, S. (2010). Tocochromanol functions in plants: antioxidation and beyond. Experimental Botany, 61(6): 1549-1566.

Gondim, F.A.; Miranda, R.S.; Filho, E.G. and Presco, T.G. (2013). Enhanced salt tolerance in maize plants induced by H2O2 leaf spraying is associated with improved gas exchange rather than with non- enzymatic antioxidant system. Theoretical and Experimental Plant Physiology, 35(4): 251-260.

Hassanein, A.M. and Azab, A.M. (1990).Towards the rational use of high salinity tolerant plants Voi. 2 Agriculture and forestry under marginal soil water conditions: Salt tolerance of grain sorghum. Stanford University, Stanford, Calif., U.S.A.O.

Hayat, S.; Mir, B.A.; Wani, A.S.; Hasan, S.A.; Irfan, M. and Ahmad, A. (2011). Screening of salt tolerant genotypes of Brassica juncea based on photosynthetic attributes. J. Plant Interact., 6: 53-60.

Hincha, D.K. (2008). Effect of Alpha-tocopherols (Vitamin E) on the stability of and lipid dynamics of model membranes mimicking the lipid composition of plant chloroplast membranes. FEBS-Letters, 582: 3687-3692.

Huang, S.; Spielmeyer. W.; Lagudah, E;S; James. R.A.; Platten, J.D. and Dennis, E.S., et al. (2006). A sodium transporter (HKT7) is a candidate for Nax1, a gene for salt tolerance in durum wheat. PlantPhysiol., 142: 1718–1727.

Hemida, K.A.; Eloufey, A.Z.; Seif El-Yazal, M.A. and Rady, M.M. (2017). Integrated effect of potassium humate and α-tocopherol applications on soil characteristics and performance of *Phaseolus vulgaris* plants grown on a saline soil. Journal Archives of Agronomy and Soil Science, 63 Issue 11:1556-1671.

Hamid, M., Ashraf, MY, and Arashad, M, et al. (2008). Influence of salicylic acid seed priming on growth and some biochemical attributes in wheat grown under saline conditions. Pakistan Journal of Botany, 40: 361- 367.

Hussein, M.M. and N.H. Abou Bakr (2018). The contribution of nano-zinc to alleviate salinity stress on cotton plants. Royal Society Open Science 5 (8): 171-809.

Hussein, M. M. and Alva, A. S. (2014). Effect of Zinc and Ascorbic acid application on the growth and photosynthetic pigments of millet plants grown under different salinity. Agric. Sci., 5:1263-1270.

Hussein, M.M. and El-Greatly, N.H. (2007). Influences of Alpha-tochopherol and potassium dihydrogen phosphate on growth and endogenous photohormones of onion plants grown under salinity stress. J. Agric. Sci., Mansoura Univ., 32 (11): 9741-9151.

Hussein, M.M. and Mandour, M.M. (1979). Influence of salinity on organic acids metabolism in corn seedlings. Ain Shams, Agric. Res. Bull., No.1142.

Hussein, M.M.; Shaaban, M.M. and El-Saady, A.M. (2008). Response of cowpea plants grown under salinity stress to PK-foliar application. American J. of Plant Physiol., 3(2): 81–88.

Hussein; M.M.; Abd El-Haddy, M.S. and, EL-Nagar, H.H. (2008). Ascorbic acid and its effect on growth and protein pattern in leaves of lupine plants grown under different salinity. Egypt. J. Agron., 30.

Hussein; M. M.; Abd El-Kader, A.A. and Alva, A. (2011). Response of growth, anatomical structure and mineral status of grain sorghum to potassium foliar fertilizer. Journal of Crop Improvement, 24: 4, 324-336.

Hussein, M. M. and Orabi, S. A. (2008). Growth and antioxidant enzymes activity in onion plants as affected by thiamine and salinity. Plant Nutrition Management under Water Stress Conditions. 17th Inter. Symposium of CIEC. Nov., 2008. NRC, Cairo, Vol. II: 260-278.

Hussein, M.M. and Aliva, A.K. (2014). Growth, yield and water use efficiency of forage sorghum as affected by NPK fertilizer and deficit irrigation. American J. of Plant Science, 2014, 5:125-126.

Hussein, M.M.; El-Faham, S.Y. and Alva, A.K. (2012). Pepper plants growth, yield, photosynthetic pigments, and total phenols as affected by foliar application of potassium under different salinity irrigation water. Agricultural Sciences, 3 (2): 241-248.

Hussein, M.M.; Sawsan Y. El-Faham; Elham Z. Abd El- Moti and Nesreen H. Abou-Baker (2017). Research Article Jojoba Irrigated with Diluted Seawater as Affected by Ascorbic Acid Application. International Journal of Agricultural Research, DOI: 10.3923/ijar.2017.1.9.

.Ibrahim, M.M.; Alsahli, A.A. and Al-Ghamdi, A. (2013). Cumulative abiotic stresses and their effect on the antioxidant defense system in two species of wheat, *Triticum durum* and *Tritucum aestivum L.* Arch. Biol. Sci., Belgrade, 65(4): 1423-1433.

Iriti, M. and Faoro, F. (2007). Review of innate and specific immunity in plants and animals. Mycopathologia, 164: 57–64.

Jackson, M.L., (1967). Soil Chemical Analysis. Prentice- Hall of India Pvt. Ltd., New Delhi, 498p.

Kausar, A. and Gull, M. (2018). Influence of salinity stress on the uptake of magnesium, phosphorus, and yield of salt susceptible and tolerant sorghum cultivars (*Sorghum bicolor L.)* Journal of Applied Biology and Biotechnology, 7(03): 53-58. May-June, 2019.

Kaya, C.; Ashraf, M.; Sonmez, O.; Tuna, A.L. and Aydemir, S. (2014). Exogenous application of thiamin promotes growth and antioxidative defense system at initial phases of development in salt-stressed plants of two maize cultivars differing in salinity tolerance, Acta Physiol. Plant.

Koyro, H.W. (2006). Effect of salinity on growth, photosynthesis, water relations and solute composition of the potential cash crop halophyte *Plantago coronopus (L.).* Environmental and Experimental Botany, 56, Issue 2: 136-146.

Khalil, S.E, Hussein, M.M. and da Silva, J.T. (2012). Roles of anti transpirants in improving growth and water relations of *Jatropha curcas L.* grown under water stress conditions. Plant Stress, 6(1): 49-54.

Kortam; M.A.; El-Zieny, H.A.; Hussein, M.M. and El- Nagar, S.M. (1987). Effect of sulphate salinity and Alar (B-9) on growth characters and chemical composition of *Cicer aretinum L.* plants. Egypt. J. Agron., 12 (1-2): 41-45.

Klute, A. (1986). "Method of Soil Analysis", 2nd ed. Part 1. Physical and Mineralogical Methods. Part 2. Chemical and Microbiological Methods Properties. Modifon, Wiscon fin. U.S.A.

Kruk, J.; Hollander-Czytko, H.; Oettmeier, W. and Trebst, (2005). Tocopherol as single oxygen scavenger in photosystem II. J. Plant Physiology, 162: 749-757.

Lukienko, P.I.; Mel'nichenko, N.G.; Zverinskii, I.V. and Zabrodskaya, S.V. (2000). Antioxidant properties of thiamin. Bull. Exp. Biol. Med., 130: 874–876.

Machado, R. M. and Serralheiro, R.P. (2017). Soil Salinity: Effect on Vegetable Crop Growth. Management Practices to Prevent and Mitigate Soil Salinization. Horticulturae, 3 (30):1-13.

Mohammadi, A.; Habibi, D.; Rohami, M. and Mafakheri, S. (2011). Effect of drought stress on antioxidant enzymes activity of some chickpea cultivars. Am-Eur. J. Agric. Environ. Sci., 11: 782-785.

Moussa; A.; Abo Lila, B.H. and Hussein, M.M. (1985). Biological changes in lupine plants under the influence of salinity types. Bull. Egypt. Soc. Physiol. Sci., 5(2):1-12.

Munné-Bosch, S. and Alegre, L. (2002). The Function of Tocopherols and Tocotrienols in Plants. Critical Reviews in Plant Sciences, Critical Reviews in Plant Sciences, 21 Issue 1: 31-57.

Munné-Bosch, S. (2005). The role of alpha-tocopherol in plant stress tolerance. J. Plant Physiol.,162(7):743-738

Nour; T.A.; Hussein, M.M. and Lotfi, L.A. (1982). Effect of boric acid and vapor gard on growth and nutrient uptake of sunflower plant grown under different salinity levels. Egypt. J. Agron., 7(1-2):25– 34

Nakano, Y. and Asada, K. (1981). Hydrogen peroxide is scavenged by ascorbate specific peroxidase in spinach chloroplasts. Plant Cell Physiol., 22: 867-880.

.Nimir, N.E.A.; Zhou, G.;. Guo, W.; Ma, B.: Lu, S. and Wangd, Y. (2017). Effect of foliar application of GA3, kinetin, and salicylic acid on ions content, membrane permeability, and photosynthesis under salt stress of sweet sorghum [*Sorghum bicolor (L.) Moench*]. Canadian Journal of Plant Science, 2017, Vol. 97, No. 3: pp. 525-535.

Niu, G.; Xu, W.; Rodriguez, D. and Sun; Y. (2012). Growth and Physiological Responses of Maize and Sorghum Genotypes to Salt Stress ISRN Agronomy, Volume 2012:1-12.

Neto, A.D.; Prisco, J.T.; Enéas-Filho, J.; Lacerda, C.F.; Silva, J.V.; Costa, P.H. and Gomes-Filh, E. (2004). Effects of salt stress on plant growth, stomatal response and solute accumulation of different maize genotypes. Braz. J. Plant Physiol., 16 (1): 31-38.

Mittler, R. (2002). Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci., 7:405–410.

Munné-Bosch, S. (2005). The role of alpha-tocopherol in plant stress tolerance. J. Plant Physiol.,162 (7):743-8.

Munns, R. (2005). Genes and salt tolerance: bringing them together. The New Phytologist., 167: 645-663.

Maas, E. Poss, J. and, Hoffman, G. (1986). Salinity sensitivity of sorghum at three growth stages. Irrigation Science, 7:1-11. doi: 10.1007/bf00255690.

Munns M. and Tester, M. (2008). Mechanisms of salinity tolerance,‖ Annual Review of Plant Biology, 59: 651- 681.

Netonodo, G.W; Onyango, G.C. and Beck, E. (2004). Sorghum and salinity: I. Response of growth, water relations, and ion accumulation to NaCl salinity. Issue 7: 743-748.

Oktay, M., I. Küfrevioğlu, I. Kocaçalışkan, and, H. Şakiroğlu, 1995. Polyphenoloxidase from Amasya apple. J Food Sci., 60(3): 494–496.

Orabi, S. A., M. M. Hussein, E. Z. Abd El-Motty, and S. Y. El-Faham, 2018. Effect of Alpha- Tochopherol and Glutamic Acid on Total Phenols, Antioxidant Activity, Yield and Fruit Properties of Mango Trees. Middle East J. Appl. Sci., 8 (4): 1229-1239.

Orabi, S.A. and M.T. Abdelhamid, 2016. Protective role of α-tocopherol on two Vicia faba cultivars against seawater-induced lipid peroxidation by enhancing capacity of anti-oxidative system. Journal of the Saudi Society of Agricultural Sciences.,15 (2): 145-154.

Orabi, S.A., I.M Talaat and L.K Balbaa, 2014. Physiological and biochemical responses of thyme plants to some antioxidants. Nusantara bioscience 6(2).

Orabi, S.A., S.D. Abo -Hussein, andF.A. Sharara, 2017 . Role of Hydrogen peroxide and α- tocopherol in alleviating the harmful effect of low temperature on cucumber (Cucumis sativas L.) plants. Middle East J. Appl.Sci.,7 (04): 914-926.

Orabi, S.A.; M. M Hussein, Zaki S.S and Sharara, F.A. (2018). Influence of hydrogen peroxide on growth, yield and biochemical constituents of canola plants grown under different irrigation intervals. August 2018Current science 07 (03): 407-418.

Pitann, B.; Schubert, S. and Mühling, K.S. (2009). f H+ pumping activity and increase in apoplastic pH of maize leaves. J. Plant Nutr. Soil Sci., 172: 535-543.

Qu, C.; Liu, C.; Gong, X.; Li, C.; Hong, M.; Wang, L. and Hong, F. (2012). Impairment of maize seedling photosynthesis caused by a combination of potassium deficiency and salt stress. Environmental and Experimental Botany, 75:134–141. Doi t10.1016/j.envexp bot.2011.08.019.

Redondo-Gomez, S.; Mateos-Naranjo, E.; Davy, A.J.; Fernández-Muñoz, F.; Castellanos, E. and Luque, T., et al. (2007). Growth and photosynthetic responses to salinity of the salt-marsh shrub Atriplex portulacoides. Ann Bot 2007; 100: 555-63.

Roy, R.C.; Sagar, A.; Tajkia, J.E.; Razzak, M.A. and Hossain, A.Z. (2018). Effect of salt stress on growth of sorghum germplasms at vegetative stage. Journal of the Bangladesh Agricultural University.1.1

Sagar, A.; Tajkia, J.E.; Haque, M.E.; Fakir, M.S. and Hossain, A.K. (2019). Screening of sorghum genotypes for salt-tolerance based on seed germination and seedling stage. Fundam. Appl. Agric., 4 (1): 735-743.

Sagar, A. (2017). Screening of sorghum germplasms for salinity tolerance based on morphophysiological and biochemical traits. MS Thesis, Bangladesh Agricultural University, Bangladesh.

Semida, W. M.; Taha, R. S.; Abdelhamid, M. T. and Rady, M. M. (2014) Foliar-applied α-tocopherol enhances salt-tolerance in *Vicia faba L.* plants grown under saline conditions. South Africa Journal of Botany, (2) 95: 24-31.

Racchi, M.L. (2013). Antioxidant Defenses in Plants with Attention to Prunus and Citrus spp. Antioxidants, 2: 340-369.

.Rhoades, J.D. and Loveday, J. (1990). Salinity in irrigated agriculture. – In: Steward, B.A., Neilsen,

D.R. (ed.): Irrigation of Agricultural Crops. Pp. 1089- 1142. ASA, CSSA, SSSA.

Sadiq, M.; Akram, N.A. and Ashraf, M. (2017). Foliar applications of alpha-tocopherol improves the composition of fresh pods of *Vigna radiata* subjected to water deficiency. Turkish Journal of Botany (Turk. J. Bot.), 41: 244-252.

Skłodowska, M.; Gapińska, M.; Gajewska, E. and Gabara, (2009). Tocopherol content and enzymatic antioxidant activities in chloroplasts from NaCl- stressed tomato plants. Acta Physiologiae Plantarum, Issue 2: 393–400.

Sai-Kachout, S.; Hamza, K. J.; Bouraoui, N. K.; Leclerc, J. C. and Ouerghi, Z. (2013). Salt-induced changes in antioxidative enzyme activities in shoot tissues of two Atriplex varieties. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41:115–121.

Sozharajan, R. and Natarajan, S. (2013). Antioxidant enzymes activity in leaves of salt stressed *Excoecaria agallocha* L. The Scientific World Journal, (2014), Asian Pacific Journal of Reproduction, 2 Issue 4: 304-308.

Saleem, M.; Ashraf, M. and Akram, N.A. (2011). Salt (NaCl) induced modulation in some key physio- biochemical attributes in okra (*Abelmoschus esculentus L*). J. Agron. Crop Sci., 197: 202-213.

Sairam, R. K. and Srivastava, G. C. (2002). Changes in antioxidant activity in sub-cellular fractions of tolerant and susceptible wheat genotype in response to long term salt stress. Plant Science, 162: 897-902.

Silber, R.; Farber, M.; Papopoulos, E.; Nervla, D.; L.; Liebes, L.; Bruch, M. and Bron, R. (1992). Glutathione depletion in chronic lymphocytic leukemia B-lymphocytes. Blood, 80:2038-2040.

Snedecor, G.W. and Cochran, W.G. (1980). "Statistical Methods" 7th ed. Iowa State Univ., Iowa, USA.

Sabir, P.; M. M. and Akram, N.A. (2011). Accession variation for salt tolerance in proso millet (*Panicum miliaceum* L) using leaf proline content and activities of some key antioxidant enzymes. J. Agron. Crop Sci., 197 (5): 340-347.

Sofo, A.; Scopa, A.; Nuzzaci, M. and Vitti, A. (2015). Ascorbate Peroxidase and Catalase Activities and Their Genetic Regulation in Plants Subjected to Drought and Salinity Stresses. Int. J. Mol. Sci. 2015 Jun; 16 (6): 13561-13578.

Szarka, A.; Tomassovics, B. and Bánheghyi, G. (2012). The ascorbate glutathione α-tocopherol triad in abiotic stress response. Int. J. Mol. Sci., 13: 4458-4483.

Sinha, A. S. R. and Rana, G.R.S. (1986). Effect of soil salinity and soil water availability on growth and chemical composition of *Sorghum halepense L*. Plant and Soil, 95 Issue 3: 411–418.

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

Sayed, S.A. and Gadallah, M.A. (2002). Effects of shoot and root application of thiamine on salt-stressed sunflower plants. Plant Growth Regulation. 36, Issue 1: 71–80.

Sharma, P.; Jha, A.B. and Dubey, R.S. (2010). Oxidative Stress and Antioxidative Defense System in Plants Growing Under Abiotic Stresses. M. Pessarakli (Ed.), Handbook of Plant and Crop Stress (third ed.), CRC Press, Florida, USA (2010), pp. 89-138.

Tabatabaei, S.A.,; Anagholi, A. (2012). Effects of salinity on some characteristics of forage sorghum genotypes at germination stage. International Journal of Agriculture and Crop Sciences 4:979–98.

Tunc-Ozdemir, M.; Miller, G.; Song, L.; Kim, J.; Sodek, A.; Koussevitzky, S.; Misra, A.N.; Mittler, R. and Shintani, D. (2009). A thiamine confers enhanced tolerance to oxidative stress in Arabidopsis1, [W][OA]. Plant Physiol., 151(1): 421-432.

Weisany, W.; Sohrabi, S.Y.; Heid, G.; Siosemardehc, A. and Badakhshan, H. (2014). Effects of zinc application on growth, absorption and distribution of mineral nutrients under salinity stress in soybean (*Glycine Max L.*). Journal of Plant Nutrition, 37, Issue 14 2255-2269.

Yasar, F.; Kusvuran, S. and S. Elialtioğlu, S. (2006). Determination of antioxidant activities in some melon (*Cucumis melo L.*) varieties and cultivars under salt stress, Journal of Horticultural Sciences and Biotechnology, 81: 627-838.

Ye, Y. R.; Waqng, W. L.; Zhang, C. S. and Chen, L. X. M. (2017). Foliar-application of α-tocopherol enhanced salt tolerance of *Carex leucochlora.* Biologia Plantarum, 61 Issue 3: 565–570.

Zanetti, G. (1979). Rabbit liver glutathione reductase, purification and properties. Arch. Biochem. Physiol., 198: 241-246.

Zagorchev, L.; Kamenova, P. and Odjakova, M. (2014). The Role of Plant Cell Wall Proteins in Response to Salt Stress. The Scientific World Journal, (2014), Article ID 764089, 9 pages.

Zheng, P.H., Dang, Y., Diao, X., and Sui, N. (2021). Molecular mechanisms of stress resistance in sorghum: Implications for crop improvement strategies**.** Annual Review of Plant Biology, 71 (2020), pp. 403-433.