Journal of Sustainable Agricultural and Environmental Sciences
https://jsaes.journals.ekb.eg/
JSAES, 2(2): 01 - 16

ISSN-Print: 2735-4377
ISSN-Online: 2785-9878

UP-REGULATION OF SOME STRESS RELATED GENES ASSOCIATED WITH SALINITY TOLERANCE IN *Oryza sativa* PLANTS UNDER PHOSPHATE STARVATION CONDITION

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J. Sust. Ag. and Env. Sci. (JSAES)

Keywords:

Oryza sativa, Salinity, Phosphorus starvation, Gene expression, Stress related genes

ABSTRACT:

Salt stress severely effect on plants growth and development, Phosphate (P) availability as one of main plant nutrient was investigated with their role in salt tolerance in Oryza sativa L plants under two level of salinity. Giza178,an Egyptian cultivated rice, was used in this investigation. Plant responses was determined as changes in fresh and dry weight, membrane properties and lipid per oxidation product (MDA)contents, total chlorophyll and carotenoids and the content of phosphors, potassium and sodium. Changes in the expression pattern some stress related genes (bZIB, hsp4, hsp13, dhn3) were quantified by RT-qPCR. Both conditions of phosphate starvation and phosphate overuse induced significant changes in all studied parameters. The combination between phosphate starvation and salinity stress improved plant performance under both tested levels of salinity. This improvement was associated with significant reduction in membrane leakage and MDA values. Significant up-regulation of all studied genes was recorded under phosphate starvation condition in stressed and non-stressed plants.

1. INTRODUCTION

Because of high content of soluble salts in the soil or irrigation water, salinity became one of the major limitations of growing or high productivity for several plants (Hillel, 2000). It affects negatively on plant metabolism by modifying osmotic adjustment, up taking of essential nutrients **(Naher and Alam, 2010)**, photosynthesis and enzyme activity **(Naveed*et al*., 2020)** and causing hormonal imbalance **(Rizwan *et al*., 2015; Basyuni *et al*., 2019).** Within the next 25 years, increased salinization of arable land is expected to cause loss of 30% of planted land and up to 50% by the year 2050 **(Wang *et al*., 2003; Cheong and Yun, 2007; Liu *et al*., 2020)**.

Egypt encounters severe salinity problems, where about 30% of all irrigated lands are affected by salt **(Zinck, 2002; Al-Naggar*et al*., 2015)**. In Egypt, expanding of agricultural area is demoded to overcome the rapid increase in population. Shortage of water resources limits this expanding and forces to use low-quality water in irrigation, which mostly causes soil salinization **(Karajeh *et al*., 2011; Osman, 2012; Osman *et al*., 2012)**.

Establishment of new strategies to minimize the sever effects of salinity is a great target for plant and crop scientists. Up-regulation of stress and growth related gene is one of the most remarkable changes associated with the acquisition of salinity tolerance in plants **(Yeo and Flowers, 1986; Yeo *et al*., 1990; Peng and Ismail, 2004; Moradi and Ismail, 2007)**. Such genes are involved in signaling, transcriptional control, protection of membranes and proteins, and scavenging of free-radical **(Wang *et al*., 2003; Omar *et al*., 2013; Omar *et al*., 2018; Elsheery *et al*., 2020)**. Controlling the expression of these genes is a target of new strategies to overcome salinity effects on some plants **(Hasegawa *et al*., 2000; Erpen*et al*., 2018)**.

Since salt tolerance is a multigenic trait controlled by a complex cascade of metabolic pathways and signaling cascades, non-genetic engineering techniques seem to be more effective in improving plant performanceand productivity under environmental stresses **(Kumar *et al*., 2017; Rajput *et al*., 2021)**.

Nutritional status of saline soil is a considered concern in inducing salt tolerance of different plant species **(Hosseini*et al*., 2004; Keshavarz and Malakouti, 2005)**. Phosphate (P) is among the most important macro nutrients for plants **(Marschner and Rengel, 2012)** and plays important roles in growth, development, reproduction, signal transduction, energy metabolism and regulates enzymatic activities in crop plants **(Ticconi and Abel, 2004; Kumar *et al*., 2021)**. Also, the application of P fertilizer improves crop productivity while it has also posed many problems; lowering the utilization efficiency of P fertilizer by plants, severe environmental pollutions and exhausting non-renewable source of P rocks **(Srivastava*et al*., 2021; Ojeda-Rivera *et al*., 2022)**. Therefore, reducing the P fertilizer was accompanied with requiring the understanding of the molecular mechanisms that regulate plant responses to P starvation **(Yuan and Liu, 2008; Hong *et al*., 2022)**. Through coping with P starvation, plants have evolved many elaborate strategies to enhance the acquisition and utilization of P from environment **(Yuan and Liu, 2008; Dissanayaka*et al*.,2021; Nie*et al*., 2021; Wang *et al*., 2021; Yan *et al*., 2022)**. Some studies indicated that P deficiency induced salt tolerance in some plants **(Kaya *et al*., 2002; Tang *et al*., 2019).** Salinity was more detrimental to the growth of some plants under high doses of P fertilizer than it was under P starvation condition **(Alatorre-Cobos*et al*., 2009; Du *et al*., 2022)**. Investigation of capability of P deficiency in improving plant growth under salinity condition is required and could be a proposed strategy to minimize hazard

effects of salinity on some crops. Rice (*Oryza sativa* L.) is one of the main stable foods for more than 3.5 billion people around the world. It is a candidate crop to grow under saline soils in Egypt **(Hussain*et al*., 2017; Leridon, 2020; Chen *et al*., 2021)**. Rice was used in the recent study to investigate the impact of phosphor level on growth and tolerance state of Giza178 (G178) genotype grown under salinity stress. Our study included determination of the changes in some morphological and biochemical responses in addition to changes in transcriptional responses of some stress related genes to understand the role of phosphorus deficiency in improving plant growth under salt stress.

2. MATERIALS AND METHODS

2.1. Plant materials and growth conditions

One cultivated Egyptian genotype of *O. sativa* (Giza 178) was used in the recent study. Rice grains of the studied genotype were surface sterilized for 5 min with ethanol 75% and for 10 min with commercially diluted NaClO (1:3, v/v) followed by three rinses with sterile distilled water. The experiment was completely randomized block design with control and two levels of salinity. The salinity was induced by diluting of sea water to 1/12 (S1) and 1/6 (S2). Half-strength Hoagland nutrient solution was used as a control condition while a modified Hoagland nutrient solution; containing 1 mM MKH_2PO_4 [low P (P1)] or 10 mM KH_2PO_4 [high P (P2)], was used to provide starvation and excess conditions of P. The experiment was carried out in aquaculture conditions using glass aquarium in dimensions of 7*25*25 cm. Seed germination was conducted in the dark at 28±1 ºC for 72 h then germination percentages were recorded. The seven days old seedlings were transferred to nutrient solution in aquaculture in glass container. Samples (14 days old seedling) were collected and immediately frozen using liquid nitrogen and kept at -80 ºC to be used for farther biochemical and molecular analysis.

2.2. *Root fresh and dry weights*

Root fresh (Fw) and dry (Dw) weightswere measured for seedlings (14 days old) grown under control and other experimental conditions. Seedlings were photographed and roots were separated for measuring Fw and Dw. Root Dw was determined for 10 seedlings of each treatment after drying at 105 ºC for 3 h and was expressed as mg per seedling.

2.3. Evaluation of lipid per oxidation product

Malondialdehyde (MDA) as a product of lipid per oxidation was evaluated as a concentration of thiobarbituric acid (TBA) as described by **Anjum*et al.* (2012)** with some modifications as described by **Zedan and Omar (2019)**. The content of MDA was expressed as $nmol.g^{-1}$Dw.

2.4. Measurement of membrane leakage

Electrolyte leakage (EL); as an indicator of membrane integrity, was measured for individual seedlings using a conductivity meter (Adwa-AD32). All measuring procedures were carried out according to **Omar *et al*. (2012)**. The conductivity of solution was expressed as μScm^{-1} FW h^{-1}.

2.5. Chlorophyll and Carotenoids content

Three replicates of 5 discs from soybean fresh leaves were taken from each treatment and weighted, Each replicate was pot in clean glass vials that contain 2 ml of 80% acetone and stored in the refrigerator at 4ºC for two days. The leaf material was bleached and decanted off. The optical density was read at wavelengths of 663, 646 and 470 nm against a blank of 80% acetone using spectrophotometer (UV190IPC) according to **Lichtenthaler and Wellburn, (1983).**

2.6. Phosphorus, sodium and potassium contents

Total phosphorus (P), sodium (Na) and potassium (K) concentrations in the seedling were measured using Atomic Absorption Spectrometry (GBC Avanta E, Victoria, Australia) at the Central Laboratory for Environmental Studies, University of kafrelsheikh, Egypt as described by **Chen *et al*. (2007)** and **Wang *et al*. (2009)**.

2.7. Analysis of gene expression

2.6.1. Total RNA extraction and cDNA synthesis

Total RNA was extracted from plant seedlings under control and all experimental conditions using EZ-10 Spin Column Plant RNA Mini-Preps Kit (BIO BASIC, CANADA INC). RNA was analyzed in 1% agarose gel for RNA integrity confirmation. The concentration and purity of RNA were measured using NanoDrop Spectrophotometer (BioDrop µLITE, UK). Samples with purity values higher than 1.8 were considered acceptable for gene expression analysis. One µg of total extracted RNA for each sample was used for cDNA synthesis according to the protocol supported by GoScript™ Reverse Transcription Kit using Oling $(dT)^{15}$ primer.

2.6.2. Quantitave analysis of gene expression.

Gene-specific primers were used for quantitative analysis of gene expression. All primers used for quantitative RT-PCR (qRT-PCR) are listed in Table (1). All used primers were designed based on sequencing data of selected genes on the website of National Center for Biotechnology Information (NCBI). Primer Primer5 software was used for primer designing. Quantitative RT-PCR reactions were conducted using TOPreal™ qPCR 2X pre-MIX SYBR Green with low ROX (enzynomics- Korea) in 20 µl reaction volume. The reactions were run on a StepOnePlus™ Real-Time PCR system

Table 1: Names, sequences and annealing temperatures (Ta) of primers used in qRT-PCR analysis

Gene name	Accession no.	Primer sequence5'-----3'	Ta (ºC)
hsp4	DQ180746	F-GGAGGAGTCGTGCAAGTACC R-TCATCACATCGCATACGGCA	54
hsp13	AY034057	F-CGGTGGTCATTTCCTTCCCA R-GAAGGGGTCAAACACGTTGC	54
dhn3	EF576194	F-TGGAGGAGTTCGTAGCAGGA R-GACGCCAGGATAATACACATCA	54
bZIP1	CT833525	F- GAGCGTACTCTGTCCCATTTAG R- GTTCCAGCGATGAGGTTGT	56
actin	X16280	F-CATGCTATCCCTCGTCTCGACCT R-CGCACTTCATGATGGAGTTGTAT	56

(Applied Bios stem™, Life technology, USA).cDNA for *actin* gene (accession no. X16280) (Table1) was used as an internal constitutively expressed control(reference gene). The reaction was conducted under standard condition using Variflex option to adjust different annealing temperature for different genes on the same plate. Data were given as means±SE of relative quantification (RQ) of gene expression for three biological replicates for each cDNA sample. RQ was calculated as $2^{-\Delta\Delta ct}$calibrated with endogenous gene and control treatment (**Livak and Schmittgen, 2001**)

2.8. Statistical analysis

All data were subjected to analysis ofvariance and mean comparisons were performed by Duncan's Multiple Range Test.

Means are presented with standard error (SE). Significant difference between means

of treatments was compared at the 5% probability level ($P \leq 0.05$).

3. RESULTS AND DISCUSSIONS

3.1 Root fresh and dry weights

Both of Fw and Dw of roots showed similar pattern in their changes under the experimental conditions (Fig.1A, B). Both levels of salinity (S1 and S2) as well as low concentration of P (P1) induced a significant reduction in root Fw and Dw. On the other hand, induced changes under the overuse of P (P2) were non-significant. Low concentration of P induced significant recovery in both root Fw and Dw of stressed plants under both levels of salinity (P1S1 and P1S2). Overuse of P induced non-significant changes in root Fw under both level of salinity (P2S1 and P2S2)

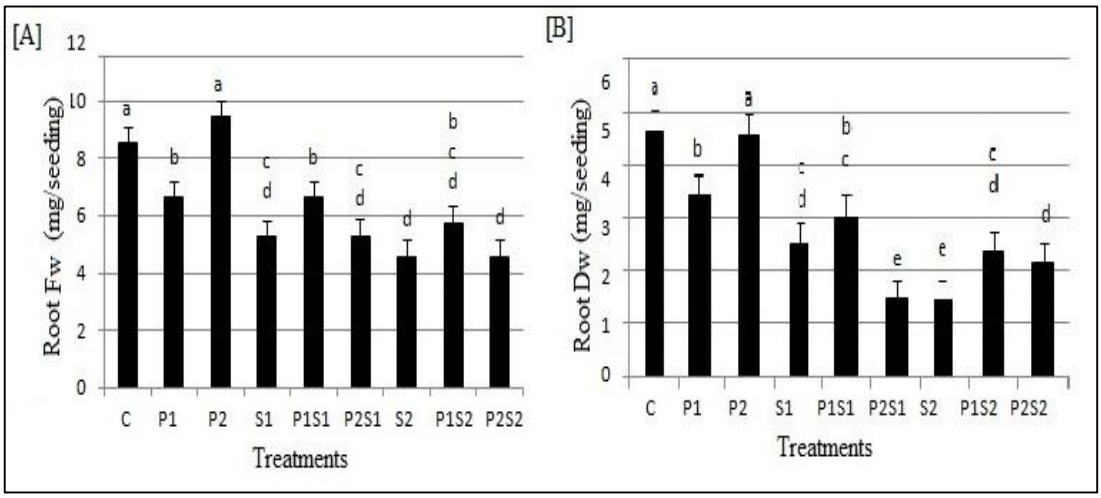

Fig. 1: Changes in fresh (Fw) and dry (Dw) weights of O. sativa roots under all experimental conditions. C: control in half-strength Hoagland nutrient solution; P1 [1 mM KH_2PO_4 (p starvation); P2 [10 mM KH_2PO_4 (P overuse)]; S1 (1/12 sea water); S2 (1/6 sea water); P1S1 (1 mM KH_2PO_4+1/12 sea water); P2S1 (10 mM KH_2PO_4+1/12 sea water); P1S2 (1 mM KH_2PO_4+ 1/6 sea water); P2S2 (10 mM KH_2PO_4+ 1/6 sea water). Solutions for all treatments were prepared in half-strength Hoagland nutrient solution. Values with different letters are significant.

(Fig.1A)on contrary, overuse of induced a significant recovery in Dw of Pstressed plants under the higher level of salinity (P2S2) (Fig.1B).Effect of Pconcentration on root growth as root length was reported in *Aeluropuslittoralis* **(Marschner, 1995)** and soybean (**Zribi et al., 2017).**Phosphorus overuse induced a reduction in root length in wheat **(Abid *et al*., 2002).** In barley, P shortage induced an increase in primary roots length (**Steingrobe *et al*., 2001)**. Changes in root growth under different P concentrationconstitute a strategy to enhance both P acquisition and water uptake (**Fujita *et al*., 2004; Maggio *et al*., 2005)**.

3.2 Rate of EL and MDA content

Both levels of salinity (S1, S2) induced an increase in rate of EL and MDA content in the studied genotype (Fig. 2) which is in accordance with data obtained previously

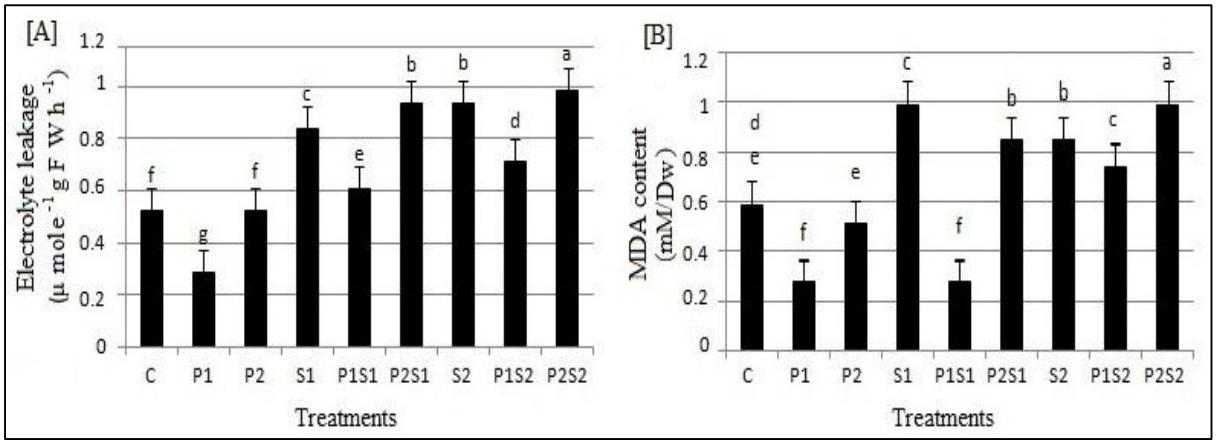

Figure 2: Changes in rate of electrolyte leakage and MDA in O. sativa seedling under all experimental conditions. C: control in half-strength Hoagland nutrient solution; P1 [1 mM KH_2PO_4 (P starvation); P2 [10 mM KH_2PO_4 (P overuse)];S1(1/12 sea water); S2 (1/6 sea water); P1S1 (1 mM KH_2PO_4+1/12 sea water); P2S1 (10 mM KH_2PO_4+1/12 sea water); P1S2 (1 mM KH_2PO_4+1/6 sea water); P2S2 (10 m KH_2PO_4+1/6 sea water). Solutions for all treatments were prepared in half-strength Hoagland nutrient solution. Values with different letters are significant

In sea fennel by **Ben-Hamed *et al.* (2007**). Phosphorus deficiency (P1) caused a significant decrease in EL rate (Fig. 2A) and MDA content (Fig. 2B). Phosphorus overuse (P2) induced non-significant reduction in EL and MDA values. Oxidative stress associated with salinity is the main reason for per oxidation of lipid subsequently, membrane damage and increasing the leakage rate (**Hafsi *et al.*, 2010)**. When stressed plants were subjected to P deficiency (P1S1 and P1S2), the Eland MDA values were significantly decreased compared with their values under both levels of salinity (Fig. 2A, B). On the other hand, increase of phosphorus and MDA values, except P2S1 for MDA which induced a significant decrease. Similar effects of P concentration were reported in barley (**TalbiZribi *et al.*, 2011**). In our results, reduction in El and MDA values under P deficit condition support the role of phosphate starvation in inducing the defense system mechanisms under salinity condition (**Ben Hamed et al., 2007; Lin et al., 2012**) with salinity stressed plants (P2S1 and P2S2) induced a significant increase in EL

3.3 Total chlorophyll and carotene

Our results revealed series of changes in total chlorophyll and carotene contents in the seedling of G178 genotype under different experimental condition (Fig. 3).

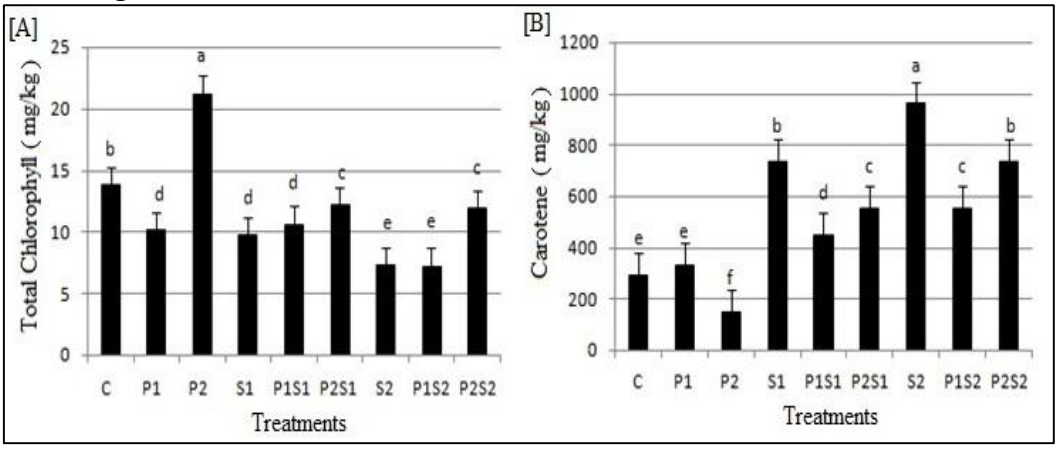

Fig. 3: Changes in total chlorophyll and carotenoids content in *O. sativa* seedling under all experimental conditions. C: control in half-strength Hoagland nutrient solution; P1 [1 mM KH_2PO_4 (P starvation); P2 [10 mM KH_2PO_4 (P overuse)]; S1 (1/12 sea water); S2 (1/6 sea water); P1S(1 mM KH_2PO_4+1/12 sea water); P2S1 (10 mM KH_2PO_4+1/12 sea water); P1S2 (1 mM KH_2PO_4+1/6 sea water); P2S2 (10 mM KH_2PO_4+1/6 sea water). Solutions for all treatments were prepared in half-strength Hoagland nutrient solution. Values with different letters are significant

Both levels of salinity (S1 and S2) induced a significant reduction in total chlorophyll (Fig.3 A). On the other hand, carotenoids content in the studied genotype showed a significant increase under both levels of salinity (Fig. 3B). Phosphorus deficiency (P1) induced a significant reduction in the total chlorophyll and non-significant increase in the carotenoids value. The P overuse (P2) caused a significant increase in the total chlorophyll content and a significant reduction in the carotenoids value. Plants subjected to P deficiency with two levels of salinity (P1S1 and P1S2) showed non-significant increase in total chlorophyll values and significant reduction in carotenoids contentscompared with salinity stressed plants. On the other hand, P overuse (P2) with salinity stressed plants (P2S1 and P2S2) induced a significant increase in total chlorophyll compared with stressed plants. In contrary, P overuse (P2) induced a significant reduction in carotenoids content in stressed plants (P2S1 and P2S2) compared with stressed plants. Increasing total chlorophyll in salinity stressed plants under P shortage condition was reported in *Brassica napus* and *Sesuviumportulacastrum*(**Yaryura *et al.*, 2009; Rabhi*et al.*, 2010**). Application of P shortage and salt stresses; single or in combination, induced significant increase in chlorophyll and carotenoids in *Catapodiumrigidum* plants (**Zribi *et al.*, 2017**).

3.4 Phosphorus, sodium and potassium contents

3.4.1 *Phosphorus (P) content*

Measurement of total P content in G178 plants under all experimental conditions (Table 2) revealed that both levels of salinity (S1 and S2) and P deficiency treatment (P1) induced significant reduction in P content. The reduction in P content in salinity stressed plants may be due to a synergistic effect of sodium, which is involved in P uptake and⁄or transport to the shoots (**Rubio *et al.*, 2001**).Phosphorus overuse treatment (P2) caused a significant increase in P content compared with plants under control condition. Similar results were obtained in soybean (**Phang *et al.*, 2009**). Application of P overuse on salinity stressed plants induced significant increases in P content compared with stressed plants at the two levels of salinity (P2S1 and P2S2). Significant recovery in P content induced in stressed plants under P deficit condition (P1S1). On the other hand, P deficit condition induced a significant reduction in P content of plants treated with the higher level of salinity (P1S2). Our results agree with those reported by (**TalbiZribi *et al.*,2011**).There is some evidence that the P-deficient plants are more salt tolerant than P-sufficient plants in maize (**Tang *et al.*, 2019**) and soybean (**Phang*et al.*, 2009**). However, the effect of salt stress on P accumulation and its toxicity varies depending on the plant environmental conditions, crop species, genotype within the species, physiological developmental stages, and external salinity concentration (**Fageria*et al.*, 2011**).

3.4.2 Sodium (Na) content

Data shown in Table (2) revealed series of changes in Na content under different experimental condition. Both levels of salinity (S1 and S2) induced a significant increase in Na content in plant leaves. Both of P deficiency (P1) and P overuse (P2) treatments induced a non-significant reduction in Na content compared with plants under control treatment. This decrease in Na content could explain the improvement in plant growth as a result of

stress decreasing. Phosphorus deficit treatment induced a significant reduction in Na content in stressed plants with higher salt concentration (P1S2). On the other hand**,** P overuse treatment for salinity stressed plants (P2S1 and P2S2) induced an increase in Na content compared with plants cultivated under the interactive effects of salinity and P deficiency. These results were confirmed by **TalbiZribi *et al*. (2011)**. Phosphorus overuse with salinity stressed plants induced an increase in Na uptake subsequently, reduced salt tolerance in soybean (**Phang *et al*., 2009**). Phosphorus availability affected Na transport to shoots where it induced the expression of Na dependent high-affinity phosphate transporter encoding gene at the plasma membrane of leaf and root cells (**Rubio *et al*., 2001**).

Table 2: Phosphorus (P), sodium (Na) and potassium (K) contents in *O. sativa* plants under all experimental conditions

Treatments	Elements		
	P	Na	K
C	6389.35^{b}	5257.2^{e}	29185^{a}
P1	3334.85^{g}	2909.5^{e}	19725^{b}
P2	6714.7^{a}	4296.8^{e}	11974.35^{e}
S1	3317.5^{g}	26142.5^{c}	12381.75^{de}
P1S1	3734.6^{f}	27327.95^{c}	17296.25^{bc}
P2S1	4597.2^{d}	33564.7^{b}	10212.5^{e}
S2	4181.25^{e}	26526.6^{c}	11974.35^{e}
P1S2	3703.05^{f}	19206.5^{d}	16062.5^{bcd}
P2S2	5270.5^{c}	39308.35^{a}	13300^{cde}

C: control in half-strength Hoagland nutrient solution; P1 [1 mM KH_2PO_4 (P starvation); P2 [10 mM KH_2PO_4 (P overuse)]; S1 (1/12 sea water); S2 (1/6 sea water); P1S1(1 mM KH_2PO_4+1/12 sea water); P2S1 (10 mM KH_2PO_4+1/12 sea water); P1S2 (1 mM KH_2PO_4+1/6 sea water); P2S2 (10 mM KH_2PO_4+1/6 sea water). Solutions for all treatments were prepared in half-strength Hoagland nutrient solution. Values with different letters are significant.

3.4.3 Potassium (K) content

Both levels of salinity (S1 and S2) induced a significant reduction in K content in the studied genotype (Table 2). Reduction in K content under salinity stress was recorded in *Hordeummaritimum* (**Hafsi *et al*., 2007; TalbiZribi *et al*., 2011**).Phodphorus deficiency (P1) and P overuse (P2) induced a decrease in K content compared with plants under control condition. When plants were subjected to P deficiency and low salinity together (P1S1), K content showed a significant increase in respect to its content under salt stress alone (S1). On the other hand, increase of P with salinity stressed plants (P2S1 and P2S2) induced non-significant changes in K content compared with stressed plants (S1 and S2).In saline soils, K^+ deficiency arises from low K^+ availability in the soil solution and/or it can be triggered by high levels of salt because of the competition between K^+ and Na^+ (**Waqas*et al*., 2021)**.

3.5 Analysis of gene expression

The quantitative analysis of transcript amount of some growth and stress-responsive genes was carried out using qRT-PCR analysis. The studied genes included; basic leucine zipper1 (*bZIP*1), heat shock protein genes (*hsp4* and *hsp13*) and dehydrin (*dhn3*). The expression level of these genes showed different patterns under different experimental conditions.

Obtained results showed significant up-regulation in the expression levels of *hsp4*,*hsp13* and *dhn3* genes in plants treated with both levels of salinity (S1 and S2) compared with the plants under control condition (Fig. 4B,C,D). The increase in expression level of *bZIP1* was non-significant (Fig. 4A).

Plants under P deficit condition (P1) showed significant up-regulation in the expression levels for all studied genes compared with those under control condition. On the other hand, the expression levels of all studied genes were significantly down regulated following the treatment with P overuse (P2) (Fig. 4A,B,C), except *hsp13* which showed non-significant changes compared with plants under control condition (Fig.4D). Stressed plants treated with low level of P (P1S1 and P1S2) showed a significant up-regulation in the expression levels of *bZIP1*, *hsp4*, *hsp13* and *dhn3* compared with non-treated stressed plants (S1 and S2). Phosphorus overuse (P2) with salinity stressed plants (P2S1 and P2S2) showed significant down regulated in the expression levels of all studied genes compared to stressed plants (S1 and S2). Up-regulation of these genes improves plant performance under salt stress condition. Heat shock protein genes (*hsp4* and *hsp13*) (Fig. 4C,D) which work as molecular chaperones help in protection of cell component and supporting the correct folding of newly synthesized proteins as they help in protein folding under stress condition (**Timperio*et al.*, 2008; Tichá*et al.*, 2020**). Dehydrin (DHN) proteins are known with their roles in protection of cell membranes and functional proteins under oxidative stress conditions (**Omar *et al.*, 2013)**. Increasing the expression level of DHNs encoding gene (*dhn3*) (Fig. 4B) under P starvation condition could help plant in avoiding severely effects of salinity (**Zedan and Omar, 2019**).

Basic leucinezipper (bZIP)s are master regulators of many central developmental and physiological processes (**Alves *et al.*, 2013**). In our results *bZIP1* was one of significantly up- regulated genes under P starvation condition alone or in combination with salinity stress (Fig. 1A). Modulation of the expression patterns of *bZIP* genes and changes in their activity often contribute to the activation of various signaling pathways and regulatory networks of different physiological processes. Recent study on plant bZIP transcription factors are pointed to their involvement in abiotic stress and development (**Alves*et al.*, 2013; Sornaraj*et al.*, 2016**).

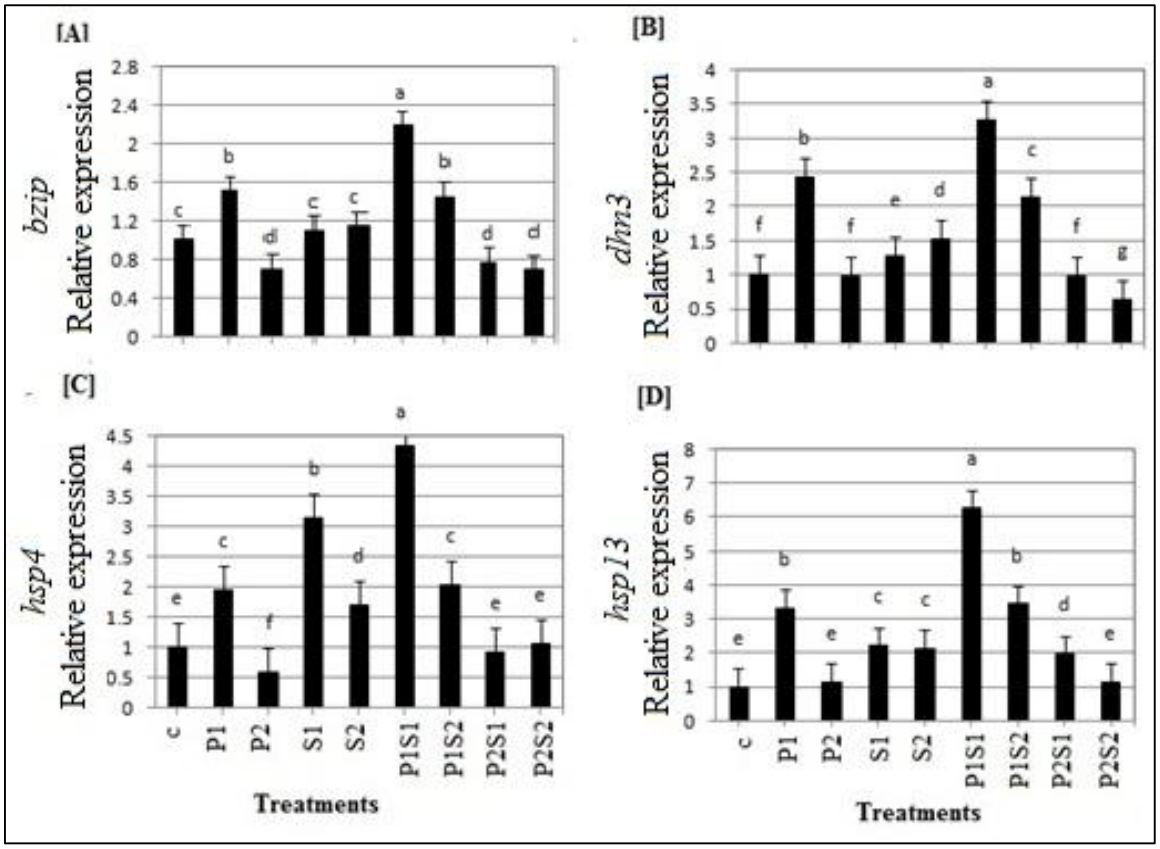

Fig. 4: Changes in relative expression of some stress and growth related genes in O. sativa seedling transcript amount using qRT-PCRunder all experimental conditions. C: control in half-strength Hoagland nutrient solution; P1 [1 mMKH_2PO_4 (p starvation); P2 [10 mM KH_2PO_4 (P overuse)]; S1(1/12 sea water); S2 (1/6 sea water); P1S1 (1 mM KH_2PO_4+1/12 sea water); P2S1 (10 mM KH_2PO_4+1/12 sea water); P1S2 (1 mM KH_2PO_4+1/6 sea water); P2S2 (10 mMKH_2PO_4+1/6 sea water). Solutions for all treatment were prepared in half-strength Hoagland nutrient solution. Values with different letters are significant.

4. CONCLUSION

This study was carried out to investigate the different growth and physiological responses of rice plants (G178 variety) cultivated under interactive effects of salinity and phosphorus availability. Phosphorus deficiency reduces the adversely effects of salinity stress. On the other hand, sufficient P supply negatively affected plant growth of rice plants under salinity conditions. The better salt tolerance of plants exposed to both stresses was explained as a result of associated improvement in plant ability to significantly increase root weight and improve membrane properties as well as the reduction in MDA and Na element content. Most interesting results were the association of P starvation with inducing the expression of some stress related genes which support the role of P deficit in inducing salt tolerance in rice plants.

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Journal of Sustainable Agricultural and Environmental Sciences
https://jsaes.journals.ekb.eg/
JSAES, 2(2): 01 - 16

ISSN-Print: 2735-4377
ISSN-Online: 2785-9878

تحفيز التعبير الجيني لبعض الجينات المرتبطة بتحمل الملوحة تحت ظروف تجويع الفوسفور في نبات الأرز

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الملخص

تهدف هذه الدراسه إلي توضيح الاختلافات في النمو والأستجابات الفسيولوجية لنباتات الأرز المنزرعة تحت مستويين مختلفين من الملوحه ومستويين مختلفين من الفوسفور. تم استخدام صنف جيزه 178 وهو أحد أصناف الأرز المصري المستزرعة. وقد أشتملت الدراسة علي تقدير أختلاف استجابة نباتات الأرز تحت الظروف التجربية المختلفة وذلك بتقدير التغيرات الحادثة في الوزن الرطب والجاف، محتوي الكلوروفيل الكلي والكاروتينات ،درجة ارتشاح الغشاء ، درجه تأكسد الدهون ومحتويات أكسدة الدهون ، محتوى النبات من عناصر الفوسفور والبوتاسيوم والصوديوم. هذا بالإضافه الي تقدير التغير الكمي في التعبير الجيني لبعض الجينات ذات الصلة بالاجهادات التأكسدية مثل (*bZIB*، *hsp4*، *hsp13*، *dhn3*) بواسطة RT-qPCR. وقد اظهرت الدراسة حدوث العديد من التغيرات في الصفات محل الدراسة تحت ظروف الملوحة وكذلك التركيزات المختلفة من الفوسفور. كما اوضحت الدراسة أن زياده الفوسفور كان له تأثيرا سلبيا علي نمو نباتات الأرز تحت ظروف الملوحة بينما أدي نقص الفوسفور (تجويع الفسفور) الي التقليل من الأثار السلبية للملوحة حيث تزامن ذلك مع تحفيز التعبير الجيني للجينات محل الدراسة مما ادي تحسين أداء النبات تحت كلا المستويين المختبرين من الملوحة. وقد اوصت الدراسة بتقليل معدلات التسميد بالفوسفات للنباتات الأرز المنزرعة تحت الظروف الملحية.