

ORIGINAL ARTICLE

**24-Epibrassinolide ameliorates the adverse effect of salt stress  
(NaCl) on pepper (*Capsicum annuum* L.)**

Ibn Maaouia-Houimli Samira \*, Bouthaina Dridi-Mouhandes,

Samia ben Mansour-Gueddes, Mounir Denden

*Department of Horticulture, High Institute of Agronomy, 4042 Chott-Mariem, Tunisia*

*Tel: +216 2159 2240*

*\*E mail: [h.samira@laposte.net](mailto:h.samira@laposte.net)*

Received January 23, 2012

The present study investigates the role of 24-epibrassinolide (EBL) in inducing plant tolerance to salinity. Seedlings of pepper (*Capsicum annuum* L.) were grown in the presence of 70 mM NaCl and were sprayed with  $10^{-6}$  M EBL at 7 days after transplantation and were sampled at 28 day. The plants exposed to NaCl exhibited a significant decline in relative growth rate, net CO<sub>2</sub> assimilation, stomatal conductance, transpiration and water use efficiency. However, the follow up treatment with EBL significantly improved the above parameters. EBL treated plants had greater relative growth rate compared to untreated plants when exposed to salt stress. Application of EBL increased photosynthesis by increasing stomatal conductance in both control and salt stressed plants and may have contributed to the enhanced growth. The water use efficiency was improved because CO<sub>2</sub> assimilation is more important than the transpiration.

*Key words: 24-epibrassinolide / pepper / NaCl / relative growth rate / gas exchange.*

## ORIGINAL ARTICLE

**24-Epibrassinolide ameliorates the adverse effect of salt stress (NaCl) on pepper (*Capsicum annuum* L.)**

Ibn Maaouia-Houimli Samira \*, Bouthaina Dridi-Mouhanded,  
Samia ben Mansour-Gueddes, Mounir Denden

*Department of Horticulture, High Institute of Agronomy, 4042 Chott-Mariem, Tunisia*

*Tel: +216 2159 2240*

*\*E mail: [h.samira@laposte.net](mailto:h.samira@laposte.net)*

Received January 23, 2012

The present study investigates the role of 24-epibrassinolide (EBL) in inducing plant tolerance to salinity. Seedlings of pepper (*Capsicum annuum* L.) were grown in the presence of 70 mM NaCl and were sprayed with  $10^{-6}$  M EBL at 7 days after transplantation and were sampled at 28 day. The plants exposed to NaCl exhibited a significant decline in relative growth rate, net CO<sub>2</sub> assimilation, stomatal conductance, transpiration and water use efficiency. However, the follow up treatment with EBL significantly improved the above parameters. EBL treated plants had greater relative growth rate compared to untreated plants when exposed to salt stress. Application of EBL increased photosynthesis by increasing stomatal conductance in both control and salt stressed plants and may have contributed to the enhanced growth. The water use efficiency was improved because CO<sub>2</sub> assimilation is more important than the transpiration.

*Key words: 24-epibrassinolide / pepper / NaCl / relative growth rate / gas exchange.*

Salinity has been considered as one of the serious environmental stress on plant growth and development as well as crop production. About 20% of irrigated agricultural land is adversely affected by salinity (Pitman and Läuchli, 2002). Moreover about one-third of the irrigated land on the earth is affected by salinity (Taiz and Zeiger, 2006). Through its osmotic effect, salinity perturbs a multitude of physiological processes including photosynthesis, a process which is the main determinant of the dry matter accumulation and

productivity of the crops. The decline in photosynthesis observed under salt stress is not only attributed to stomata closure leading to a reduction of intercellular CO<sub>2</sub> concentration, but also to non-stomata factors (Qin *et al.*, 2010). Non-stomatal restriction of net assimilation may originate from a reduced efficiency or regeneration capacity of ribulose-1,5-biphosphate (RuBP) carboxylase, a sensitivity of photosystem II to NaCl, or a reduced leaf chlorophyll concentration (Lycoskoufis *et al.*, 2005). Salinity

reduces the ability of plants to utilize water and causes a reduction in growth rate, as well as changes in plant metabolic processes (Munns, 2002). All these events lead to poor plant growth and productivity.

Various agronomic and physiological practices are applied to minimize the adverse effects of salinity on the normal functioning of plants. Moreover, plant growth regulators, both natural and synthetic, are widely applied to agricultural crops as a means of crop improvement (Hayat *et al.*, 2010).

Brassinosteroids (BRs) represent a group of naturally occurring steroidal lactones widely distributed in plant kingdom. Studies with BR biosynthesis mutants and BR insensitive mutants of *Arabidopsis thaliana* have also provided evidence that BRs are essential for plant growth (Clouse and Sasse, 1998). Since the identification of the first BRs, almost one hundred structurally related compounds were isolated from various parts of many plant species (Holá 2010). BRs promote plant growth through multiple mechanisms like cell division, cell elongation, vascular differentiation, germination, rhizogenesis, flowering, and modulation of gene expression (Sasse 2003). Exogenous application of BRs promote leaf photosynthesis by positively regulating synthesis and activation of a variety of photosynthetic enzymes including Rubisco (Xia *et al.*, 2009), and this activity of BRs may contribute to increased crop yield after BRs application (Hayat *et al.*, 2000; Yu *et al.*, 2004). In addition to stimulating growth, BRs have an anti-stress effect on plants. Previous studies showed that salt tolerance of rice (Özdemir *et al.*, 2004), chickpea (Ali *et al.*, 2007), Indian mustard (Ali *et al.*, 2008) and mung bean (Hayat *et al.*, 2010) could be markedly enhanced by the application of brassinosteroids.

Pepper (*Capsicum annum*) is considered sensitive (Lycoskoufis *et al.*, 2005) or moderately-sensitive to salt stress (Chartzoulakis and Klapaki, 2000). Salinity hampers pepper growth more during vegetative phase (Villa-Castorena *et al.*, 2003). Therefore, the present study was conducted with an objective to ameliorate pepper salt tolerance by using 24-epibrassinolide, a highly active and stable steroidal hormone (Khripach *et al.*, 2000). For this purpose, pepper plants were sprayed with 24-epibrassinolide solution and the effects of salt exposure for 28 days on growth and photosynthesis parameters were studied.

## MATERIALS AND METHODS

### Plant material and experimental conditions

Experiment was carried out at 'High Institute of Agronomy, Chott Meriam' (Tunisia) with pepper plants (*Capsicum annum* L. cv. Beldi) grown in glasshouse conditions: where the temperature for day/night was 28/20°C and the relative humidity was 60-80%. Uniforms pepper seedlings (true leaves) were transplanted at a rate of one plant per 17 cm plastic pot containing peat. A week after transplantation, the seedlings were irrigated with salt water (70 mM NaCl) and were sprayed with distilled water (control) or  $10^{-6}$  M 24-epibrassinolide (EBL was dissolved in a minimal volume of ethanol and then made up to volume with distilled water as described in our previous study (Houimli *et al.* 2008). The plants were sprayed once on the leaves early in the morning. A Hoagland's solution was added weekly to the plants.

### Growth analysis

Plant growth was determined destructively over two harvests, the first at the time of EBL application ( $t_1$ ) and the second occurred 21 days after EBL application ( $t_2$ ), to examine plant responses to EBL treatment. The leaf area was

measured using a LI-3100 leaf meter (LI-COR. Inc., Lincoln, NE, USA). Plants materials (leaves, stem and roots) were dried in a 70 °C oven for 3 days to determine dry weights. Six individual plants were randomly selected per treatment at each harvest. The relative growth rate (RGR, in  $\text{mg g}^{-1}\text{day}^{-1}$ ), the net assimilation rate (NAR, in  $\text{mg cm}^{-2}\text{j}^{-1}$ ) and the leaf area ratio (LAR, in  $\text{cm}^2\text{g}^{-1}$ ) of each plant was estimated using the equations:

$$\text{RGR} = (\ln W_2 - \ln W_1) / (t_2 - t_1)$$

$$\text{NAR} = (W_2 - W_1) / [(A_2 - A_1) / (t_2 - t_1)]$$

$$\text{LAR} = 0.5[(LA_1/W_1) + (LA_2/W_2)]$$

Where  $W_1$  and  $A_1$  are the plant dry weight and total leaf area, respectively, at the initial time ( $t_1$ ), and  $W_2$  and  $A_2$  are the plant dry weight and total leaf area at the final harvest ( $t_2$ ) (Hunt, 1990).

#### Chlorophyll fluorescence

Chlorophyll fluorescence measurements were made in attached leaves with a portable fluorometer F.I.M, 1500, ADC (Fluorescence Induction Monitor 1550, Analytical Development Company Limited). Leaves were dark-adapted for 30 min, then dark fluorescence  $F_0$ , maximal fluorescence  $F_m$ , and photochemical yield  $F_v/F_m$  ( $F_v = F_m - F_0$ ) were recorded.

$F_0$  is the initial fluorescence emission by antenna Chl a molecules.  $F_m$  is the maximum total fluorescence value;  $F_v = F_m - F_0$  is the variable fluorescence. The  $F_v/F_m$  ratio measures the efficiency of excitation energy captured by open PSII reaction centres representing the maximum capacity of light-dependent charge separation (Krause and Weis, 1991).

#### Gas exchange

Photosynthetic rate ( $P_n$ ), stomatal conductance ( $G_s$ ) and transpiration ( $E$ ) measurements were made on the upper fourth or fifth fully expanded leaf, between 9:00 h and 11:00h using a portable gas exchange system (CI-301 CO<sub>2</sub> GAS ANALYSER, CID, Inc.). The atmospheric conditions during the experiments were: PAR,  $1100 \pm 50 \mu\text{mol m}^{-2}\text{s}^{-1}$ ;  $C_i$ ,  $280 \pm 15 \mu\text{mol mol}^{-1}$ ; atmospheric CO<sub>2</sub>,  $355 \pm 5 \mu\text{mol mol}^{-1}$ ; relative humidity,  $65 \pm 5\%$ ; atmospheric temperature,  $25 \pm 2$  °C.

#### Statistical analysis

Data was subjected to one-way analysis of variance (ANOVA) and the mean differences were compared by Duncan Test. Each value was the mean of six replicates ( $n=6$ ) and comparisons with  $P$ -values  $<0.05$  were considered significantly different.

**Table 1:** Evaluation of relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) of pepper plants (var. Beldi) were subjected to foliar application of 24-epibrassinolide (EBL) under control or saline condition.

Treatments	RGR ( $\text{mg g}^{-1}\text{j}^{-1}$ )	NAR ( $\text{mg cm}^{-2}\text{j}^{-1}$ )	LAR ( $\text{cm}^2\text{g}^{-1}$ )
Control	56.2 b	193.2 b	22.21 b
EBL	70.3 a	217.5 a	24.39 ab
NaCl	49.9 c	178.5 c	21.02 b
NaCl+EBL	62.0 b	197.7 b	24.04 ab

Data were reported as means ( $n=6$ ). Means were separated by Duncan's test, different letters in a single column show statistically significant differences for  $P<0.05$ .

**Table 2.** Chlorophyll fluorescence parameters (F<sub>0</sub>, F<sub>m</sub> and F<sub>v</sub>/F<sub>m</sub>) of pepper plants (var. Beldi) were subjected to foliar application of 24-epibrassinolide (EBL) under control or saline condition.

Treatments	F <sub>0</sub>	F <sub>m</sub>	F <sub>v</sub>	F <sub>v</sub> /F <sub>m</sub>
Control	289 a	1596 a	1307 a	0.819 a
EBL	288 a	1540 a	1252 a	0.813 a
NaCl	291 a	1582 a	1291 a	0.816 a
NaCl +EBL	281 a	1509 a	1228 a	0.814 a

Data were reported as means (n=6). Means were separated by Duncan's test, different letters in a single column show statistically significant differences for P<0.05.

**Table 3.** Effects of 24-epibrassinolide (10<sup>-6</sup> M) and NaCl-stress (70mM) on the photosynthetic rate (P<sub>n</sub>, μmol CO<sub>2</sub> m<sup>-2</sup>.s<sup>-1</sup>), stomatal conductance (G<sub>s</sub>, mmol m<sup>-2</sup>.s<sup>-1</sup>), transpiration (E, mmol H<sub>2</sub>O m<sup>-2</sup>.s<sup>-1</sup>) and water use efficiency (WUE, μmol CO<sub>2</sub>/mmol H<sub>2</sub>O) in pepper leaves.

Treatments	P <sub>n</sub>	E	G <sub>s</sub>	WUE
Control	14.2 b	3.6 a	301 b	4.0 ab
EBL	16.3 a	3.8 a	334 a	4.3 a
NaCl	9.6 d	2.9 b	229 d	3.3 bc
NaCl +EBL	12.3 c	3.3 ab	279 c	3.7 b

Data were reported as means (n=6). Means were separated by Duncan's test, different letters in a single column show statistically significant differences for P<0.05.

## RESULTS

### Growth analysis

Application of 70 mM NaCl to pepper plants adversely influenced relative growth rate (RGR) as compared with control plants (Table 1). Analysis of RGR components shows that this inhibition is due to a significant reduction of net assimilation rate (NAR) and not to the leaf expansion (LAR). When plants grown in the presence or absence of sodium chloride are subjected to EBL treatment, RGR was significantly improved compared with control plants (Table 1). This increase is accompanied by significant increases in the NAR and unchanged for the LAR.

### Chlorophyll fluorescence

The changes in PSII photochemistry were investigated in the dark-adapted leaves. Table 2 shows that neither NaCl nor EBL application affected the minimal Chl a fluorescence, F<sub>0</sub>, the maximal Chl a fluorescence, F<sub>m</sub> and therefore the

maximum quantum efficiency of PSII photochemistry (F<sub>v</sub>/F<sub>m</sub>).

### Gas exchange

The net assimilation (P<sub>n</sub>), transpiration (E) and stomatal conductance (G<sub>s</sub>) were significantly (p<0.05) declined in the plants, exposed to NaCl-stress (Table 3). It appears from our results that the decline in net photosynthesis (P<sub>n</sub>) is mainly attributed to the decrease in stomatal conductance, but not to the damage of the photosynthetic apparatus, since the activity of PSII (estimated by the ratio of F<sub>v</sub>/F<sub>m</sub>) was preserved in the dark adapted leaves under NaCl-stress (Table 2).

Treatment with EBR has a positive effect on the photosynthetic activity of control and NaCl-stressed plants, which is associated with a parallel positive effect on stomatal conductance. In relative terms, the impact of EBR on carbon fixation is greater than the impact on stomatal conductance (and thus the leaf

transpiration); the result is a positive effect of EBR on plant water use efficiency (Table 3).

## DISCUSSION

The growth analysis showed that 70 mM NaCl treatment induced a significant reduction in relative growth rate (RGR) of pepper plants as compared to the control (Table 1). This is consistent with previous reports that pepper plants are relatively sensitive to salt stress (Chartzoulakis and Klapaki, 2000, Lycoskoufis *et al.*, 2005; Huez-López *et al.*, 2011). This reduction may be the result of slower leaf expansion (LAR) (Cramer *et al.*, 1994) or the reduction of photosynthetic activity (NAR) (Bayuelo-Jiménez *et al.*, 2003). Our results show that inhibition of biosynthetic activity (RGR) was estimated by a decline in photosynthesis (NAR) rather than a reduction in leaf area (LAR). This suggests that photosynthesis is the limiting factor for growth. Changes in CO<sub>2</sub> assimilation may be attributable to either stomatal or non-stomatal factors or both (Bethke and Drew 1992). Our data show that the presence of salt in the root medium caused a reduction in stomatal conductance (Gs) of pepper plants (Table 2). Similar results were obtained by Martínez-Ballesta *et al.* (2004) and Lycoskoufis *et al.* (2005), where Gs was reduced by salt treatments. A decrease in Gs was observed for the NaCl treatments, probably caused by closure of the stomata or a decrease in water uptake through the roots (Martínez-Ballesta *et al.*, 2004). The decrease in water flow by salinity may cause lowering in leaf water content that would result in stomatal closure in order to maintain their water status (Robinson *et al.*, 1997). The stomatal closure is likely the first plant defense against desiccation and an important factor to control carbon fixation (Da Silva *et al.*, 2008). Measurements of Chl *a* fluorescence parameters were attempted to evaluate

the direct effects of salt stress on PSII photochemistry. Results revealed that NaCl treatment have no effect on leaf photochemistry, and photosystem II (PSII) remained resistant to salt stress as reported by Belkhdja *et al.* (1999) and Zribi *et al.* (2009), they showed no significant change in the photosynthetic quantum yield (Fv/Fm) in response to NaCl treatments. It seems from the results that the decline in net photosynthesis (Pn) may result from a reduced stomatal conductance, but not to injuries to the photosynthetic apparatus, since PSII activity (estimated by the ratio Fv/Fm) of dark-adapted leaves were preserved under salt stress (Table 2). Parallel decreases in stomatal conductance and net photosynthesis due to NaCl salinity have been reported for pepper plants (Chartzoulakis and Klapaki, 2000; De Pascale *et al.*, 2003; Martínez-Ballesta *et al.*, 2004).

Exogenous application of EBL improved the RGR of pepper plants. These results are not surprising since brassinosteroids were implicated in cell elongation and differentiation (Hu *et al.*, 2000). However, the increase in RGR was attributed to the increase in the physiological growth parameter (NAR) rather than the morphological growth parameter (LAR). Thus suggests that EBL-induced salt tolerance in pepper plant. Since salinity inhibits plant growth by adversely affecting various physiological and biochemical processes including photosynthesis, antioxidant capacity, and ion homeostasis (Ashraf, 2004), it is suggested that BRs enhanced growth of salt stressed plants might have been due to BRs-induced changes in these physiological or biochemical processes (Özdemir *et al.*, 2004; Ali *et al.*, 2007; Ali *et al.*, 2008; Hayat *et al.*, 2010). For example, Ali *et al.* (2008) reported that EBL increased growth in Indian mustard plants could be related to enhanced activity of antioxidative

enzymes and proline level that protect the plants from oxidative damage. Therefore, photosynthesis which is a major controlling factor for plant growth and yield might have been increased due to EBL application (Yu *et al.*, 2004). In this study, foliar application of EBL enhanced CO<sub>2</sub> assimilation rate in pepper plants. Therefore, the promotion of growth in pepper plants by EBL under NaCl-stress appears at least correlatively linked with enhanced photosynthesis. Increased growth and CO<sub>2</sub> assimilation following the application of BRs under salt stress have been reported in case the mustard (Hayat *et al.*, 2007; Ali *et al.*, 2008), and mung bean plant (Hayat *et al.*, 2010). EBL activated the rate of photosynthesis may be by increasing stomatal conductance (Table 3), facilitating the diffusion of carbon dioxide into the stomatal cavity (Fariduddin *et al.*, 2006). However, EBL has no effect on quantum efficiency (Table 2). Similarly, no significant changes of Fv/Fm value in wheat, grown hydroponically in EBL-containing medium (Ali *et al.*, 2008) or foliar sprayed (Shahbaz *et al.*, 2008). Yu *et al.* (2004) noted that EBL significantly increased the light saturated net CO<sub>2</sub> assimilation rate from 3 h to 7 d after spraying with 0.1 mg l<sup>-1</sup> EBL in *Cucumis sativus*. Increased CO<sub>2</sub> assimilation rate in EBL treated leaves was accompanied by a higher quantum yield of PSII electron transport, mainly due to a significant increase in the photochemical quenching and unchanged efficiency of energy capture by open PSII reaction centers (Yu *et al.*, 2004). Moreover, BRs had a positive effect on the activation of Rubisco based on increased maximum Rubisco carboxylation rates ( $V_{c,max}$ ), total Rubisco activity and, to a greater extent, initial Rubisco activity induced by an enhanced expression of genes encoding other Calvin cycle genes after BRs treatment might also play a positive role in

RuBP regeneration/ $(J_{max})$ , thereby increasing maximum carboxylation rate of Rubisco ( $V_{c,max}$ ). Thus, BRs promote photosynthesis by positively regulating synthesis and activation of a variety of photosynthetic enzymes including Rubisco (Xia *et al.*, 2009).

In conclusion, the foliar spray of 24-epibrassinolide has a positive effect on growth and plant metabolism. Indeed, it reduces some disruption caused by NaCl-stress: attenuation of growth inhibition and stimulation of photosynthetic characteristics of pepper under control or saline conditions. These results suggest a potential use of 24-epibrassinolide which to be confirmed by other experiments and field trials.

## REFERENCES

- Ali, B., Hayat, S. and Ahmad, A. (2007) 28-Homobrassinolide ameliorates the saline stress in chickpea (*Cicer arietinum* L.). *Environ. Exp. Bot.*, 59, 217-223.
- Ali, B., Hayat, S., Fariduddin, Q. and Ahmad, A. (2008) 24-Epibrassinolide protects against the stress generated by salinity and nickel in *Brassica juncea*. *Chemosphere.*, 72, 1387-1392.
- Bayuelo-Jiménez, J.S., Debouck, D.G. and Lynch, J.P. (2003) Growth, gas exchange, water relations, and ion composition of *Phaseolus* species grown under saline conditions. *Field Crop Res.*, 80, 207-222.
- Belkhdja, R., Morales, F., Abadia, A. and Medrano, H. (1999) Effects of salinity on chlorophyll fluorescence and photosynthesis on barley (*Hordeum vulgare* L.) grown under a triple-line-source sprinkler system in the field. *Photosynthetica.*, 36, 375-378.
- Bethke, P.C. and Drew, M.C. (1992) Stomatal and nonstomatal components to inhibition of

- photosynthesis in leaves of *Capsicum annuum* during progressive exposure to NaCl salinity. *Plant Physiol.*, 99, 219-226.
- Chartzoulakis, K. and Klapaki, G. (2000) Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. *Sci. Hort.*, 86, 247-260.
- Clouse, S. D. and Sasse, J. M. (1998) Brassinosteroides: Essential regulators of plant growth and development. *Ann. Rev.*, 49, 427-451.
- Cramer, G.R., Alberico, G.J. and Schmidt, C. (1994) Salt tolerance is not associated with the sodium accumulation of two maize hybrids. *J. Aust Plant Physiol.*, 21, 675-692.
- Da Silva E.C., Nogueira, R.J.M.C. de Araujo, F.P. de Melo N.F. and Neto, A.D.A. (2008) Physiological responses to salt stress in young umbu plants. *Environ. Exp. Bot.*, 63, 147-157.
- De Pascale S., Ruggiero, C. and Barbieri, G. (2003) Physiological responses of pepper to salinity and drought. *J. Am. Soc. Hort. Sci.*, 128, 48-54.
- Fariduddin Q., S. Hayat, B. Ali and Ahmad, A. (2006) Effect of 28- homobrassinolide on the nitrate reductase, carbonic anhydrase activities and net photosynthetic rate in *Vigna radiata*. *Acta Bot. Croat.*, 65, 19-23.
- Hayat, S., Ahmad, A., Mobin, M., Hussain, A. and Fariduddin, Q. (2000) Photosynthetic rate, growth, and yield of mustard plants sprayed with 28-homobrassinolide. *Photosynthetica.*, 38, 469-471.
- Hayat, S., Hasan, S.A., Yusuf, M., Hayat, Q. and Ahmad, A. (2010) Effect of 28-homobrassinolide on photosynthesis, fluorescence and antioxidant system in the presence or absence of salinity and temperature in *Vigna radiata*. *Environ. Exp. Bot.*, 69, 105-112.
- Holá, D. (2010) Brassinosteroids and photosynthesis. In: Brassinosteroids: a class of plant hormone. S. Hayat and A. Ahmad. Springer. pp, 143-192.
- Houimli, S.M., Denden, M. and El Hadj, S.B. (2008) Induction of salt tolerance in pepper (*Capsicum annuum*) by 24-epibrassinolide. *Eur. Asian J. BioSci.*, 2, 83-90.
- Huez-López, M. A., Ulery, A. L., Samani, Z., Picchioni G. and Flynn. R.P. (2011) Response of chile pepper (*Capsicum annuum* L.) to salt stress and organic and inorganic nitrogen sources: I.growth and yield. *Trop. Subtrop. Agroecosystems.*, 14, 137-147.
- Hu Y., Bao, F. and Li, J. (2000) Promotive effect of brassinosteroids on cell division involves a distinct CycD3-induction pathway in *Arabidopsis*. *Plant. J.*, 24,693-701
- Hunt R. (1990) Basic growth analysis. Plant growth analysis for beginners. Acad. Div. Unwin Hyman Ltd, London, p. 111.
- Khripach, V., Zhabinskii, V. and De Groot, A. (2000) Twenty years of brassinosteroids: steroidal plant hormones warrant better crops for the XXI century. *Annu. Bot.*, 86, 441-447.
- Krause, G.H. and Weis, E. (1991) Chlorophyll fluorescence and photosynthesis: the basics, *Annu. Rev. Plant Physiol. Plant Mol. Biol.*, 42, 313-349.
- Lycoskoufís, I.H., Savvas, D. and Mavrogianopoulos, G. (2005) Growth, gas exchange, and nutrient status in pepper (*Capsicum annuum* L.) grown in recirculating nutrient solution as affected by salinity



- imposed to half of the root system. *Sci. Horti.*, 106, 147-161.
- Martinez-Ballesta, M.C., Martinez, V. and Carvajal, M. (2004) Osmotic adjustment, water relations and gas exchange in pepper plants grown under NaCl or KCl. *Environ. Exp. Bot.*, 52, 161-174.
- Munns, R. (2002) Comparative physiology of salt and water stress. *Plant Cell. Environ.*, 25, 239-250.
- Özdemir, F., Bor, M., Demiral, T. and Turkan, I. (2004) Effects of 24-epibrassinolide on seed germination, seedling growth, lipid peroxidation proline content and antioxidative system of rice (*Oryza sativa* L.) under salinity stress. *Plant. Gr. Regu.*, 42, 203-211.
- Pitman, M.G. and Läuchli, A. (2002) Global impact of salinity and agricultural ecosystems. In: Salinity: Environment – Plants – Molecules, A. Läuchli and U. Lüttge (Editors.). Kluwer Academic Publishers, Dordrecht, pp: 3-20.
- Qin, J., Dong, W.Y., He1, K.N., Yu, Y., Tan, G.D., Han, L., Dong, M., Zhang, Y.Y., Zhang, D., Li, A.Z. and Wang, Z.L. (2010) NaCl salinity-induced changes in water status, ion contents and photosynthetic properties of *Shepherdia argentea* (Pursh) Nutt. Seedlings. *Plant. Soil. Environ.*, 56, 325-332.
- Robinson, M.F., Very, A.A. Sanders, D. and Mansfield, T.A. (1997) How can stomata contribute to salt tolerance? *Ann. Bot.*, 80, 387-393.
- Sasse, J.M. (2003) Physiological actions of brassinosteroids: An update. *J. Plant. G. Regu.*, 22, 276-288.
- Shahbaz, M. and Ashraf, M. (2007) Influence of exogenous application of Brassinosteroid on growth and mineral nutrients of wheat (*Triticum aestivum* L.) under saline conditions. *Pak. J. Bot.*, 39, 513-522.
- Taiz, L. and Zeiger, E. (2006) Plant Physiology. Benjamin/Cummings, Redwood City, California.
- Villa-Castorena, M., Ulery, A.L., Catal6n-Valencia, E.A. and Remmenga, M.D. (2003) Salinity and nitrogen rate effects on the growth and yield of chile pepper plants. *Soil Sci. Soc. Am. J.*, 67, 1781-1789.
- Xia, X.J., Huang, L.F., Zhou, Y.H., Mao, W.H., Shi, K., Wu, J.X., Asami, T., Chen, Z. and Yu, J.Q. (2009) Brassinosteroids promote photosynthesis and growth by enhancing activation of Rubisco and expression of photosynthetic genes in *Cucumis sativus*. *Planta.*, 230, 1185-1196.
- Yu, J.Q., Huang, L.F., Hu, W.H., Zhou, Y.H., Mao, W.H., Ye, S.F. and Nogués, S. (2004) A role for brassinosteroids in the regulation of photosynthesis in *Cucumis sativus*. *J. Exp. Bot.*, 55, 1135-1143.
- Zribi, L., Gharbi, F. Rezgui, F. Rejeb, S. Nahdi, H. and Rejeb, M.N. (2009) Application of chlorophyll fluorescence for the diagnosis of salt stress in tomato “*Solanum lycopersicum* (variety Rio Grande)”. *Sci. Horti.*, 120, 367-372.