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USE OF CALCIUM SULPHATE IN ALLEVIATING SALINITY EFFECTS IN TOMATO (Lycopersicon esculentum Mill.)

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By

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USE OF CALCIUM SULPHATE IN ALLEVIATING SALINITY EFFECTS IN TOMATO (*Lycopersicon esculentum* Mill.)

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Januay 2018

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The fertigation system which uses soilless culture media is one of the efficient systems in cultivating variety of crops. However, the efficiency of this system is likely to be disrupted by abiotic stress such as salinity which contributed detrimental effects to plant growth and yield of crops. Hence, this study was conducted to evaluate the response of lowland tomato in the presence of medium and high concentration of salinity in terms of growth, physiology and yield, and to improve the yield and fruit quality using calcium as supplementation in the nutrient solution. Two tomatoes cultivars (Pearl and MT1) were grown under soilless culture system with basic nutrient solutions containing three different levels of NaCl (0, 70 and 140 mM) and observed at 4, 8 and 12 weeks after treatment. Significant effect of cultivars within NaCl treatment were shown by the plant height, total leaf area, shoot and root dry weight, and root to shoot ratio where they were all decreased as the NaCl level increased from week 4 until 12 after treatment. Cultivars within NaCl treatments showed significant effect on photosynthetic rate, stomatal conductance, total chlorophyll content and relative water content by showing the reduction from week 4 until 12 after treatment. The potassium and calcium concentration in both leaves and roots showed significant effect but decreased under saline condition, while sodium and chloride have a significantly high uptake due to the significant increase in electrolyte leakage. Salt stress had triggered the accumulation of proline in the leaves of the tomatoes, but not for lipid peroxidation. Salinity decreased total fruit yield to 83% for Pearl and 88% for MT1 at 140 mM NaCl. However, increasing NaCl concentration significantly increased total soluble solids, titratable acidity and blossom-end rot incidence. Tomato Pearl was more tolerant to salinity with higher fruit yield compared to MT1 at 70 mM NaCl. In order to improve tomato yield under saline condition, three concentrations of calcium sulphate (0, 2.5 and 10 mM) were added in the basic nutrient solution containing 70 mM NaCl. The addition of calcium significantly improved the growth of Pearl (plant height, total leaf area, shoot and root dry weight, shoot to root ratio) throughout the experiment. Photosynthetic rate, stomatal conductance, total chlorophyll content showed better activity at 2.5 mM $CaSO_4$. The potassium and calcium concentration in the leaves of Pearl was well corrected after a supplementary of calcium by reducing the membrane

permeability to Na^+ and Cl^-. Fruit yield, total soluble solids, titratable acidity, ascorbic acid, and blossom-end rot were significantly improved at 10 mM $CaSO_4$. The supplementation of calcium was also effective in reducing the accumulation of proline and MDA content through improving the activity of antioxidant, phenolic and flavonoid content. In conclusion, application of calcium in the nutrient solution to alleviate salt stress effects is one of the simple practices that can be used in the soilless culture system which improves the growth, yield and quality of the fruits.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGGUNAAN KALSIUM SULFAT DALAM MENGURANGKAN KESAN KEMASINAN DALAM TOMATO (*Lycopersicon esculentum* Mill.)

Oleh

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Sistem fertigasi menggunakan media kultur tanpa tanah merupakan salah satu sistem yang berkesan dalam penanaman pelbagai tanaman. Walau bagaimanapun, keberkesanan sistem ini boleh terjejas oleh tekanan abiotik seperti kemasinan yang memberi kesan buruk terhadap pertumbuhan tanaman dan hasil tanaman. Justeru itu, kajian ini dijalankan untuk melihat tindak balas tomato tanah rendah terhadap kepekatan kemasinan yang sederhana dan tinggi dari segi pertumbuhan, fisiologi dan hasil, dan juga meningkatkan hasil dan kualiti buah dengan penambahan kalsium di dalam larutan nutrisi. Dua kultivar tomato (Pearl dan MT1) ditanam di bawah sistem kultur tanpa tanah dengan larutan nutrisi yang mengandungi tiga tahap NaCl yang berbeza (0, 70 dan 140 mM) dan diperhatikan pada minggu 4, 8 dan 12 selepas rawatan. Kesan yang ketara oleh kultivar di dalam rawatan NaCl ditunjukkan oleh ketinggian pokok, jumlah keluasan daun, berat kering pucuk dan akar, dan nisbah akar kepada pucuk di mana kesemuanya berkurangan apabila tahap NaCl meningkat dari minggu 4 hingga 12 selepas rawatan. Kultivar di dalam rawatan NaCl menunjukkan kesan yang ketara pada kadar fotosintesis, konduktor stomatal, jumlah kandungan klorofil dan kandungan air relatif pada minggu tertentu dengan menunjukkan penurunan dari minggu 4 hingga 12 selepas rawatan. Kepekatan kalium dan kalsium di dalam daun dan akar mennjukkan interaksi yang ketara namun menurun dalam keadaan kemasinan, sementara natrium dan klorida di ambil secara tinggi disebabkan oleh peningkatan yang ketara pada ketelusan membran. Tekanan garam telah merangsang pengumpulan prolin di dalam daun tomato, namun tidak pada lipid peroksida. Kemasinan telah menurunkan hasil buah kepada 83% untuk Pearl dan 88% untuk MT1 pada 140 mM NaCl. Walau bagaimanapun, peningkatan kepekatan NaCl telah meningkatkan jumlah pepejal larut, keasidan titrat dan kejadian reput pangkal secara signifikan. Tomato Pearl lebih toleransi terhadap kemasinan dengan hasil buah yang lebih tinggi berbanding MT1 pada 70 mM NaCl. Bagi meningkatkan hasil tomato di bawah keadaan kemasinan, tiga kepekatan kalsium sulfat (0, 2.5 dan 10 mM) telah ditambah ke dalam larutan nutrisi yang mengandungi 70 mM NaCl. Tambahan kalsium telah menambah baik secara ketara terhadap pertumbuhan Pearl (ketinggian pokok, jumlah keluasan daun, berat kering pucuk dan akar, nisbah pucuk kepada akar)

sepanjang eksperimen. Kadar fotosintesis, konduktor stomatal, jumlah kandungan klorofil menunjukkan aktiviti yang lebih baik pada 2.5 mM $CaSO_4$, namun kandungan air relatif di dalam Pearl tertinggi pada 10 mM $CaSO_4$. Kepekatan kalium dan kalsium di dalam daun Pearl telah dibaik pulih selepas penambahan kalsium dengan mengurangkan ketelusan membran kepada Na^+ dan Cl^-. Hasil buah, jumlah pepejal larut, keasidan titrat, asid askorbik, dan reput pangkal bertambah baik secara ketara pada 10 mM $CaSO_4$. Penambahan kalsium juga berjaya dalam mengurangkan pengumpulan prolin dan kandungan MDA melalui penambahbaikan aktiviti antioksida, fenolik dan kandungan flavonoid. Kesimpulannya, aplikasi kalsium di dalam larutan nutrisi untuk menghindar kesan tekanan garam merupakan salah satu praktikal yang mudah digunakan di dalam sistem fertigasi untuk meningkatkan pertumbuhan, hasil dan kualiti buah.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

%	Percent
°C	Degree celcius
$AgNO_3$	Silver nitrate
$AlCl_3$	Aluminium chloride
ANOVA	Analysis of variance
AOS	Active oxygen species
BER	Blossom-end rot
$CaSO_4$	Calcium sulphate
CCD	Coconut coir dust
Chl	Chlorophyll
cm^2	Centimetre square
CRD	Completely randomized design
DPPH	1,1-diphenyl-2-picrylhydrazyl
$dS\ m^{-1}$	Deci Siemens per meter
DW	Dry weight
EC	Electrical conductivity
EDTA	Ethylenediaminetetraacetic acid
EL	Electrolyte leakage
FRAP	Ferric reducing antioxidant potential
FW	Fresh weight
GAE	Gallic acid equivalent
gs	Stomatal conductance
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulphuric acid
ha	Hectare

HCl	Hydrochloric acid
K_2CrO_4	Potassium chromate
L	Litre
MDA	Malondialdehyde
mL	Millilitre
mM	Milimolar
mS cm^{-1}	Mili Siemens per centimetre
Na_2CO_3	Sodium carbonate
NaCl	Sodium chloride
$NaNO_2$	Sodium nitrite
NaOH	Sodium hydroxide
Pn	Photosynthetic rate
ROS	Reactive oxygen species
RWC	Relative water content
SOD	Superoxide dismutase
TA	Titratable acidity
TBA	Thiobarbituric acid
TCA	Trichloroacetic acid
TPTZ	2,4,6-tri (2-pyridyl)-*s*-triazine
TSS	Total soluble solids
UV	Ultraviolet
w/v	Weight per volume
WAT	Week after treatment

CHAPTER 1

INTRODUCTION

1.1 Background of study

Salinity stress is an abiotic stress that is accountable for decreasing crop yields and stimulate the osmotic stress by depleting cellular water content and osmotic potential (Zhang et al., 2011). According to the Food and Agriculture Organization (FAO), about 6.5% (831 million ha) of the world's total area (12.78 billion ha) is affected by salt in soils (Sankar et al., 2011). Salt when present either externally or internally, can be toxic to plant. Normally, sodium chloride (NaCl) is a major salt in this case. Excess sodium ions (Na^{+}) in soils are toxic to most crops, but it can be inhibited by high concentration of chloride ions (Cl^{-}). High NaCl level in the rhizosphere can change the nutritional requirement of the plants, in which they need to regulate the mechanism of nutrient uptake in order to survive.

Halophytes are plants that are naturally grown under high saline condition and are tolerant to salt stress (Zhu, 2007). A plant that cannot tolerate to salt is called glycophytes. Tomato is one of the examples of glycophyte plants that is moderately tolerant to salinity. Significant reductions on growth, yield and fruit quality of crops under saline condition has been reported in many literatures such as pepper, tomato, pumpkin, strawberry and rice (Chartzoulakis and Klapaki, 2000; Kaya et al., 2002; Sevengor et al., 2011; Kaya et al., 2003; Anbu and Sivasankaramoorthy., 2014). In Malaysia, there are two types of tomato; highland and lowland, which are grown under soilless culture system in a protected environment structure (PES). Unfortunately, the NaCl stress is still prevalent under soilless culture. The excess of salt in nutrient solution provided to the plants could be one of the causes for salinity stress. Moreover, water used for irrigation, especially groundwater that is affected by salt, could also contribute to salinity stress.

One of the potential solutions, which have been hypothesized to ameliorate salt stress, is increasing the concentration of calcium ions (Ca^{2+}). Calcium (Ca) is important in stabilizing the cell membrane, working as a cementing agent in the cell wall, regulating ion transport, and controlling ion exchange behaviour (Hossain and Nonami, 2012; Marschner, 1995). Ca has been well documented in ameliorating the negative effects of NaCl in previous studies such as in tomato, papaya, strawberry and rice (Tuna et al., 2007; Madani et al., 2014; Kaya et al., 2002; Anbu and Sivasankaramoorthy., 2014). Ca is readily displaced from its membrane binding sites by other cations that can reduce its availability, thus, increasing the external concentration of calcium to greatly counteract this displacement (Lynch and Läuchli, 1988).

Tomato or *Lycopersicon esculentum* Mill. is one of the top consumed vegetable in the world as it is rich in antioxidants, vitamin C and E. In Malaysia, the commercial tomatoes are cultivated under a controlled environment in highland areas, especially in

Cameron Highland (Pahang), Lojing (Kelantan), and Ranau (Sabah). As Malaysia is targeting on exporting tomatoes to meet the international demand, lowland tomatoes has been introduced in Johor. Commercial cultivars of lowland tomatoes comprise of MT1 and MT11 from Malaysian Agricultural Research and Development Institution (MARDI), and other cultivars like the Pearl, Roma, and Momotaro from local companies. The cultivation of tomatoes is not an easy task as a number of cultural practices are needed to be done to ensure crop productivity. However, the most distinctive effect seen when tomato is cultivated under saline condition is the occurrence of blossom end rot (BER) on the fruits, which will lower its total yield. Many assumptions have been made over BER production, especially the ones regarding to calcium deficiency in the fruits, but some claimed that it happened solely due to salt stress.

Source of water is very crucial for maintaining the growth of plants. Malaysia may not face severe water scarcity just yet, but in the future, our world may be lacking in clean water. An alternative of using saline water for irrigational purpose in agriculture is possible, especially for countries that are near to coastal areas such as in Oman, Saudi Arabia (Al-Maskri et al., 2010). The usage of saline water resulted on a high loss of crop production as well as the quality of crop itself. However, salinity may not only give detrimental effects on plants. In fact, a number of previous studies done on abiotic stress showed that the crops have better fruit quality in stress compared to non-stress plants by enhancing the sugar content and organic acid production (Gao et al., 1996). However, very limited information can be accessed regarding on lowland tomatoes in Malaysia being exposed to salinity. This study is fundamental in order to provide more information on how plants respond to salt stress in the physiological way and promote solutions on alleviating salt stress effects as well as enhancing the fruit quality of lowland tomato. By using the plant physiological and metabolic understanding, this study was carried out in two experiments: 1) Salinity effects on growth, physiology and yield in tomato grown in soilless culture; 2) Supplementary of calcium in improving yield and quality of tomato under salinity stress.

1.2 Objectives

This study was done to evaluate the response of lowland tomato to salinity and calcium supplement on growth, physiological changes, yield and fruit quality.

The specific objectives of this study were:

1. To determine the effect of salinity on growth, physiological changes and yield of two lowland tomato cultivars in soilless culture system,
2. To assess the effects of salinity level on proline and lipid accumulation in both lowland tomato cultivars, and
3. To determine the best combination of tomato cultivar and salinity level for higher yield production.
4. To determine effects of supplemented calcium on growth and physiology of lowland tomato under salinity stress.
5. To determine effects of calcium in enhancing yield and quality attributes of lowland tomato under salinity stress.
6. To investigate role of calcium in alleviating salinity stress and blossom-end rot of tomato in soilless culture.

REFERENCES

Adams, P. and Ho, L. C. (1992). The susceptibility of modern tomato cultivars to blossom-end rot in relation to salinity. *Journal of Horticultural Sciences*, *67*, 827-839.

Adams, P. and Ho, L. C. (1993). Effects of environment on the uptake and distribution of calcium in tomato and on the incidence of blossom-end rot. *Plant Soil*, *154*, 127-132.

Adams, P., Davides, J. N. and Winsor, G. W. (1978). Effect of nitrogen, potassium and magnesium on the quality and chemical composition of tomato grown in peat. *Journal of Horticultural Sciences*, *53*, 115-122.

Agri-Food Business Development Center. (2012, April 19). Pelan Pemasaran tomato bagi tempoh 2002-2010. Retrieved from http://www.agribdc.com

Ahmad, P., Sarwat, M., Bhat, N.A., Wani, M.R., Kazi, A.G. and Tran, L. (2015). Aleviation of cadmium toxicity in *Brassica juncea* L. (Czern & Coss.) by calcium application involves various physiological and biochemical strategies. *PLOS ONE, 10* (1), 1-17.

Ahmadi, A. and Baiker, D. A. (2000). Stomatal and non-stomatal photosynthesis limited factors in wheat under drought stress condition. *Iranian Journal of Agricultural Sciences*, *31*, 813-825.

Ahuja, I. (2010). Plant molecular stress responses face climate change. *Trends in Plant Science*, *15*, 664-674.

Akram, M. S. and Ashraf, M. (2011). Exogenous apoplication of potassium dihydrogen phosphate can alleviate the adverse effects of salt stress on sunflower (*Helainthus annuus* L.). *Journal of Plant Nutrition*, *34*, 1041-1057.

Alam, M.Z., Stuchbury, T.R., Naylor, E.L. and Rashid, M. A. (2004). Effect of salinity on growth of some modern rice cultivar. *Journal of Agronomy*, *3*(1): 1-10.

Alam, S. M. (1999). Nutrient uptake by plants under stress conditions. In M. Pessarakli (Eds.), *Handbook of Plant and Crop Stress* (pp. 285-314). New York, USA: Marcel Dekker, Inc.

Alarcon, A. L. and Murcia, F. (2000). Cultivo en lana de roca. In A. L. Alarcon (Eds.), *Tecnologia para cultivos de alto rendimiento* (pp. 245-253). Murcia, Spain: Novedades Agricolas.

Ali, H. E. M. and Ismail, G. S. M. (2014). Tomato fruit quality as influenced by salinity and nitric oxide. *Turkish Journal of Botany*, *38*, 122-129.

Allen, G. J., Chu, S. P., Harrington, C. L., Schumacher, K., Hoffmann, T., Tang, Y. Y., Grill, E. and Schroeder, J. I. (2001). A defined range of guard cell calcium oscillation parameters encodes stomatal movements. *Nature*, *411*, 1053-1057.

Allen, G. J., Chu, S. P., Schumacher, K., Shimazaki, C. T., Vafeados, D., Kemper, A., Hawke, S. D., Tallman, G., Tsien, R. Y., Harper, J. F., Chory, J. and Schroeder, J. I. (2000). Alteration of stimulus-specific guard cell calcium oscillations and stomatal closing in *Arabidopsis* det3 mutant. *Science*, *289*, 2338-2342.

Al-Harbi, A.R., Al-Omran, A.M., Alenazi, M.M. and Wahb-Allah, M.A. (2015). Salinity and deficit irrigation influence tomato growth, yield and water use efficiency at different developmental stages. *International Journal of Agriculture and Biology, 17,* 241-250.

Al-Maskri, A., Al-Kharusi, L., Al-Miqbali, H. and Khan, M.M. (2010). Effects of salinity stress on growth, of lettuce (*Lactuca sativa*) under closed-recycle nutrient film technique. *International Journal of Agriculture and Biology, 12,* 377-380.

Al-Whaibi, M., Siddiqui, M. H. and Basalah, M. O. (2012). Salicyclic acid and calcium-induced protection of wheat against salinity. *Protoplasma*, *249*, 769-778.

Amal, A. M. and Amina, A. A. (2008). Alterations of some secondary metabolites and enzymes activity by using exogenous antioxidant compound in onion plants grown under sea water stress. *American-Eurasian Journal of Scientific Research*, *3* (2), 139-146.

Amjad, M., Akhtar, J., Anwar-Ul-Haq, M., Imran, S. and Jacobsen, S. (2014). Soil and foliar application of potassium enhances fruit yield and quality of tomato under salinity. *Turkish Journal of Biology*, *38*, 208-218.

Anbu, D. and Sivasankaramoorthy, S. (2014). Ameliorative effect of $CaCl_2$ on growth, membrane permeability and nutrient uptake in *Oryza sativa* grown at high NaCl salinity. *International Letters of Natural Sciences, 3*, 14-22.

Anjum, S.A., Wang, L., Farooq, M., Khan, I. and Xue, L. (2011). Methyl jasmonate-induced alteration in lipid peroxidation, antioxidative defence system and yield in soybean under drought. *Journal of Agronomy and Crop Science*, *197*, 296-301.

Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology*, *24*, 1-15.

Arshi, A., Ahmad, A., Aref, I. M. and Iqbal, M. (2010). Calcium interaction with salinity-induced effects on growth and metabolism of soybean (*Glycine max* L.) cultivars. *Journal of Environmental Biology*, *31* (5), 795-801.

Arts, I. C. W. and Hollman, P. C. H. (2005). Polyphenols and disease risk in epidemiologic studies. *The American Journal of Clinical Nutrition*, *81* (1 Suppl), 317S-325S.

Ashraf, M. and Harris, P. J. C. (2013). Photosynthesis under stressful environments: An overview. *Photosynthetica*, *51*, 163-190.

Ayala-Astorga, G. I. and Alcaraz-Melendez, L. (2010). Salinity effects on protein content, lipid peroxidation, pigments and proline in *Paulownia imperialis* (Siebold & Zuccarini) and *Paulownia fortune* (Seemann & Hemsley) grown *in vitro*. *Electronic Journal of Biotechnology*, *13*, 1-15.

Bakht, J., Shafi, M., Jamal, Y. and Sher, H. (2011). Response of maize (*Zea mays* L.) to seed priming with NaCl and salinity stress. *Spanish Journal of Agricultural Research*, *9*, 252-261.

Barickman, T. C., Kopsell, D. A. and Sams, A. E. (2014). Foliar applications of abscisic acid decrease the incidence of blossom-end rot in tomato fruit. *Scientia Horticulturae*, *179*, 356-362.

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

Belda, R. M. and Ho, L. C. (1993). Salinity effects on the network of vascular bundles during tomato fruit development. *Journal of Horticultural Sciences*, *68*, 557-564.

Bhattarai, D. R. and Gautam, D. M. (2006). Effect of harvesting method and calcium on post harvest physiology of tomato. *Nepal Agriculture Research Journal*, *7*, 37-41.

Bohnert, H. J. and Sheveleva, E. (1998). Plant stress adaptations-makinf metabolism move. *Current Opinion in Plant Biology*, *1*, 267-274.

Bor, M., Özdemir, F. and Türkan, I. (2003). The effect of salt stress on lipid peroxidation and antioxidants in leaves of sugar beet *Beta vulgaris* L. and wild beet *Beta maritima* L. *Plant Science*, *164*, 77-84.

Borgognone, D., Cardarelli, M., Rea, E., Lucini, L. and Colla, G. (2014). Salinity source-induced changes in yield, mineral composition, phenolic acids and flavonoids in leaves of artichoke and cardoon grown in floating system. *Journal of the Science of Food and Agriculture*, *94*, 1231-1237.

Büssis, D. and Heineke, D. (1998). Acclimation of potato plants to polyethylene glycol-induced water deficit. II. Contents and subcellular distribution of organic solutes. *Journal of Experimental Botany*, *49*, 1361-1370.

Cabañero, F. J., Martínez, V. and Carvajal, M. (2004). Does calcium determine water uptake under saline conditions in pepper plants, or is it water flux which determines calcium uptake?. *Plant Science*, *166*, 443-450.

Cabot, C., Sibole, J. V., Barcelo, J. and Poschenrieder, C. (2009). Sodium-calcium interactions with growth, water, and photosynthetic parameters in salt-treated beans. *Journal of Plant Nutrition and Soil Science*, *172*, 637-643.

Cachorro, P., Ortiz, A. and Cerda, A. (1994). Implications of calcium nutrition on the response of *Phaseolus vulgaris* L. to salinity. *Plant and Soil*, *159*, 205-212.

Caines, A. and Shennan, C. (1999). Interactive effects of Ca^{2+} and NaCl salinity on the growth of two tomato genotypes differing in Ca^{2+} use efficiency. *Plant Physiology and Biochemistry*, *37*, 569-576.

Campos, C. A. B., Fernandes, P. D., Gheyi, H. R., Blanco, F. F., Goncalves, C. B. and Campos, S. A. F. (2006). Yield and fruit quality of industrial tomato under saline irrigation. *Scientia Agricola (Piracicaba, Braz.)*, *63*, 146- 152.

Canene-Adams, K., Campbell, J. K., Zaripheh, S., Jeffery, E. H. and Erdman, J. W. (2005). The tomato as a functional food. Symposium: relative bioactivity of functional foods and related dietary supplements. *Journal of Nutrition*, *135*, 1226-1230.

Champigny, M. L. and Talouizte, A. (1981). Photosynthate distribution and metabolic fate in relation to nitrogen metabolism in wheat seedlings. In G. Akoyunoglou (Eds.), *Photosynthesis: IV. Regulation of carbon metabolism*. (pp. 645-652). Philadeplhia: Balban Inf. Science Services.

Chartzoulakis, K. and Klapaki, G. (2000). Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. *Scientia Horticulturae, 86*, 247-260.

Chaves, M. M., Flexas, J. and Pinheiro, C. (2009). Phototsynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. *Annals of Botany*, *103*, 551-560.

Chookhampaeng, S., Pattanagul, W. and Theerakulpisut, P. (2008). Effects of salinity on growth, activity of antioxidant enzymes and sucrose content in tomato (*Lycopersicon esculentum* Mill.) at reproductive stage. *ScienceAsia*, *34*, 069-075.

Chutipaijit, S., Cha-Um, S. and Sampornpailin, K. (2009). Differential accumulations of proline and flavonoids in indica rice varieties against salinity. *Pakistan Journal of Botany*, *41* (5), 2497-2506.

Claussen, W. (2002). Growth, water use efficiency, and proline content of hydroponically grown tomato plants as affected by nitrogen source and nutrient concentration. *Plant and Soil*, *247*, 199-209.

Cleland, R. E., Virk, S. S., Taylor, D. and Björkman, T. (1990). Calcium, cell walls and growth. In R. T. Leonard, and P. K. Hepler (Eds.), *Calcium in Plant Growth* (pp. 9–16). Rockville, Maryland: American Society of Plant Physiologists.

Colla, G., Rouphael, Y., Cardarelli, M., Tullio, M., Rivera, C.M. and Rea, E. (2008). Alleviation of salt stress by arbuscular mycorrhizal in zucchini plants grown at low and high phosphorus concentration. *Biology and Fertility of Soils, 44,* 501-509.

Conde, A., Silva, P., Agasee, A., Conde, C. and Gerós, H. (2011). Mannitol transport and mannitol dehydrogenase activities are coordinated in *Olea japonica* under salt and osmotic stress. *Plant and Cell Physiology*, *52*, 1766-1775.

Coolong, T., Mishra, S., Barickman, C. and Sams, C. (2014). Impact of supplemental calcium chloride on yield, quality, nutrient status, and postharvest attributes of tomato. *Journal of Plant Nutrition*, *37*, 2316-2330.

Coombs, J., Hind, G., Leegood, R. C., Tieszen, L. L. and Voshak, A. (1987). Analytical techniques. In J. Coombs, D. O. Hall, S. P. Long, and J. M. O. Scurlock (Eds.), *Techniques in Bioproductivity and Photosynthesis 2nd Edition* (pp. 219-220). UK: Pergamon Press.

Cooper, A. J. (1979). *The ABC of NFT: Nutrient Film Technique: The world's first method of crop production without a solid rooting medium*. London: Growers Book.

Costa, C., Dwyer, L. M., Zhou, X., Dutilleul, P., Hamel, C., Reid, L. M. and Smith, D. L. (2002). Root morphology of contrasting maize genotypes. *Agronomy Journal*, *94*, 96-101.

Costa, J. M. and Heuvelink, K. (2005). The tomato crop and industry. In E. Heuvelink (Eds), *Tomatoes* (pp. 1-19). Oxfordshire: CAB International.

Cramer, G. R., Läuchli, A. and Epstein, E. (1986). Effect of NaCl and $CaCl_2$ on ion activities in complex nutrient solution and root growth of cotton. *Plant Physiology*, *8*, 792-797.

Cramer, G.R., Läuchli, A. and Polito, V.S. (1985). Displacement of Ca^{2+} by Na^+ from the plasmalemma of root cells: A primary response to salt stress?. *Plant Physiology, 79,* 2017-211.

Cuartero, J. and Fernández-Muñoz, R. (1999). Tomato and salinity. *Scientia Horticulturae*, *78*, 83-125.

Daneshmand, F., Arvin, M. J. and Kalantari, K. M. (2010). Physiological responses to NaCl stress in three wild species of potato in vitro. *Acta Physiologiae Plantarum*, *32*, 91-101.

Davies, J. N. (1964). Effect of nitrogen, phosphorus and potassium fertilizer on the non-volatile organic acids of tomato fruit. *Journal of the Science of Food and Agriculture*, *15*, 665-673.

De Abreu, I. N. and Mazzafera, P. (2005). Effect of water and temperature stress on the content of active constituents of *Hypericum brasiliense* Choisy. *Plant Physiology and Biochemistry*, *43*, 241-248.

de Freitas, S. T., Amarante, C. V. T., Labavitch, J. M. and Mitcham, E. (2010). Cellular approach to understand bitter pit development in apple fruit. *Postharvest Biology and Technology*, *57*, 6-13.

de Freitas, S. T., McElrone, A. J., Shackel, K. A. and Mitcham, E. J. (2014). Calcium partitioning and allocation and blossom-end rot development in tomato plants in response to whole-plant and fruit-specific abscisic acid treatments. *Journal of Experimental Botany*, *65*, 235-247.

de Freitas, S. T., Shackel, K. A. and Mitchem, J. (2011). Abscisic acid triggers whole-plant and fruit-specific mechanisms to increase fruit calcium uptake and prevent blossom end rot development in tomato fruit. *Journal of Experimental Botany*, *62*, 2645-2656.

De Pascale, S., Maggio, A., Fogliano, V., Ambrosino, P. and Ritieni, A. (2001). Irrigation with saline water improves carotenoids content and antioxidant activity of tomato. *Journal of Horticultural Science and Biotechnology, 76,* 447-453.

Debouba, M., Gouia, H., Suzuki, A. and Ghorbel, M.H. (2006). NaCl stress effects on enzymes involved in nitrogen assimilation pathway in tomato '*Lycopersicon esculentum*'seedlings. *Journal of Plant Physiology*, *163*, 1247-1258.

Delauney, A. J. and Verma, D. P. S. (1993). Proline biosynthesis and osmoregulation in plants. *The Plant Journal: For Cell and Molecular Biology*, *4*, 215-223.

Demidchik, V., Stralsova, D., Medvedev, S.S., Pozhvanov, G.A., Sokolik, A. and Yurin, V. (2014). Stress-induced electrolyte leakage: the role of K^+ -permeable channels and involvement in programmed cell death and metabolic adjustment. *Journal of Experimental Botany, 65* (5), 1259-1270.

Department of Agriculture (2013). Hectarage, production and value of production of main vegetables by district, Pahang, 2013, *Vegetables and Cash Crops Statistic*, p. 59-68.

Desingh, R. and Kanagaraj, G. (2007). Influence of salinity stress on photosynthesis and antioxidative systems in two cotton varieties. *General and Applied Plant Physiology*, *33*, 221-234.

Dolatabadian, A., Sanavy, S. A. M. M. and Chashmi, N. A. (2008). The effects of foliar application of ascorbic acid (Vitamin C) on antioxidant enzymes activities, lipid peroxidation, and proline accumulation of canola (*Brassica napus* L.) under conditions of salt stress. *Journal of Agronomy and Crop Science*, *194*, 206-213.

Dorais, M., Ehret, D. L. and Papadopoulos, A. P. (2008). Tomato (*Solanum lycopersicum*) health components, from the seed to the consumer. *Phytochemistry Reviews*, *7*, 231-250.

Dorais, M., Papadopoulos, A. P. and Gosselin, A. (2001). Influence of electrical conductivity management on greenhouse tomato yield and fruit quality. *Agronomie*, *21*, 367-383.

Dordas, C. (2009). Foliar application of calcium and magnesium improves growth, yield, and essential oil yield of oregano (*Origanum vulgare* ssp. *hirtum*). *Industrial Crops and Products*, *29*, 599-608.

Dorothy, S. (2012, April 23). Tomatodisease prevention & cure: Blossom end rot. Retrieved from http://tomatoheadquarters.com/tomatoes-farm/tomato-disease-prevention-cure-blossom-end-rot/#lightbox/1/

Eghball, B. and Maranville, J. W. (1993). Root development and nitrogen influx of corn genotypes grown under combined drought and nitrogen stresses. *Agronomy Journal*, *85*, 147-152.

Elkahoui, S., Hernández, J. A., Abdelly, C., Ghrir, R. and Limam, F. (2005). Effects of salt on lipid peroxidation and antioxidant enzyme activities of *Catharanthus roseus* suspension cells. *Plant Science*, *168*, 607-613.

Esfandiari, E., Shekari, F., Shekari, F. and Esfandiari, M. (2007). The effect of salt stress on antioxidant enzymes activity and lipid peroxidation on the wheat seedling. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *35*, 48-56.

Fanasca, S., Colla, G., Rouphael, Y. and Saccardo, F. (2006). Evolution of nutritional value of two tomato genotypes grown in soilless culture as affected by macrocation proportions. *HortScience*, *41* (7), 1584-1588.

Fang, Z., Bouwkamp, J. and Solomos, T. (1998). Chlorophyllase activities and chlorophyll degradation during leaf senescence in non-yellowing mutant and wild type of *Phaseolus vulgaris* L. *Journal of Experimental Botany*, *49*, 503-510.

Farkhondeh, R., Nabizadeh, E. and Jalilnezhad, N. (2012). Effect of salinity stress on proline content, membrane stability and water relations in two sugar beet cultivars. *International Journal of AgriScience, 2 (5),* 385-392.

Federal Agricultural Marketing Authority (FAMA). (2015, August 14). Statistik utama pemasaran FAMA 2014. Retrieved from http://www.fama.gov.my/documents/10157/f3d27dd0-f3a3-4d94-ac01-bf5dd08022ec

Feng, G., Zhang, F. S., Xl, L., Tian, C. Y., Tang, C. and Rengel, Z. (2002). Improved tolerance of maize plants to salt stress by arbuscular mycorrhiza is related to higher accumulation of soluble sugars in roots. *Mycorrhiza*, *12*, 185-190.

Foolad, M. R. (2004). Recent advances in genetics of salt tolerance in tomato. *Plant Cell, Tissue and Organ Culture*, *76*, 101-119.

Fridovich, I. (1986). Biological effects of the superoxide radical. *Archives of Biochemistry and Biophysics*, *247*, 1-11.

Gao, Z., Sagi, M. and Lips, M. (1996). Assimilate allocation priority as affected by nitrogen compounds in the xylem sap of tomato. *Plant Physiology and Biochemistry, 34*, 807-815.

Georgios, A., Dimou, M., Flemetakis, E., Plati, F., Katinakis, P. and Drossopoulos, J.B. (2004). Immunolocalization of carbonic anhydrase and phosphoenolpyruvate carboxylase in developing seeds of *Medicago sativa*. *Plant Physiology and Biochemistry, 42,* 181-186.

Ghoulam, C., Foursy, A. and Fares, K. (2002). Effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. *Environmental and Experimental Botany*, *47*, 39-50.

Giriji, C., Smith, B.N. and Swamy, P.M. (2002). Interactive effects of sodium chloride and calcium chloride on the accumulation of praline and glycine betaine in peanut (*Arachis hypogaea* L.). *Environmental and Experimental Botany, 47,* 1-10.

González, I.N., Valverde, V.G., Alonso, J.G. and Periago, M.J. (2011). Chemical profile, functional and antioxidant properties of tomato peel fiber. *Food Research International, 44*, 1528-1535.

Grattan, S. R. and Grieve, C. M. (1999). Salinity-mineral nutrient relations in horticultural crops. *Scientia Horticulturae*, *78* (1-4), 127-157.

Guichard, S., Gary, C., Leonardi, C. and Bertin, N. (2005). Analysis of growth and water relations of tomato fruits in relation to air vapour pressure deficit and plant fruit load. *Journal of Plant Growth Regulation*, *24*, 201-213.

Gunes, A., Inal, A., Alpaslan, M., Eraslan, F., Bagci, E. G. and Cicek, N. (2007). Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. *Journal of Plant Physiology*, *164*, 728-736.

Hakiman, M. and Maziah, M. (2009). Non enzymatic and enzymatic antioxidant activities in aqueous extract of different *Ficus deltoidea* accessions. *Journal of Medicinal Plants Research*, *3* (3), 120-131.

Han, S., Tang, R., Anderson, L. K., Woerner, T. E. and Pei, Z. M. (2003). A cell surface receptor mediates extracellular Ca^{2+} sensing in guard cells. *Nature*, *425*, 196-200.

Hao, X. and Papadopoulos, A. P. (2004). Effects of calcium and magnesium on plant growth, biomass partitioning, and fruit yield of winter greenhouse tomato. *Horticultural Science*, *39* (3), 512-515.

Hare, P. D. and Cress, W. A. (1997). Metabolic implications of stress-induced proline accumulation in plants. *Plant Growth Regulation*, *21*, 79-102.

Harun, R.M.R. (1989). Potential productivity of hydroponically-grown tomatoes in the Genting Highlands, Malaysia. *Pertanika, 12*, 293-298.

Hasegawa, P., Bressan, R. A., Zhu, J. K. and Bohnert, H. J. (2000). Plant cellular and molecular responses to high salinity. *Annual Review of Plant Physiology and Plant Molecular Biology*, *51*, 463-499.

Hatami, E., Esna-Ashari, M. and Javadi, T. (2010). Effect of salinity on some gas exchange characteristics of grape (*Vitis vinifera*) cultivars. *International Journal of Agriculture and Biology*, *12*, 308-310.

Heath, R. L. and Packer, L. (1968). Photoperoxidation in isolated chloroplasts. I. Kinetics and stoichiometry of fatty acid peroxidation. *Archives of Biochemistry and Biophysics*, *125*, 189-198.

Hendrich, B. A. (2006). Flavonoid-membrane interactions: possible consequences for biological effects of some polyphenolic compounds. *Acta Pharmacologica Sinica*, *27*, 27-40.

Hernandez, J. A., Ferre, M. A., Jimenez, A., Barcelo, A. R. and Sevilla, F. (2001). Antioxidant systems and $O^{-2\ (-)}$ / H_2O_2 production in the apoplast of pea leaves. Its relation with salt-induced necrotic lesions in minor veins. *Plant Physiology*, *127*, 817-831.

Hichem, H., Mounir, D. and Naceur, E. A. (2009). Differential responses of two maize (*Zea mays* L.) varieties to salt stress: Changes on polyphenols composition of foliage and oxidative damages. *Industrial Crops and Products*, *30*, 144-151.

Ho, L. C. and White, P. J. (2005). A cellular hypothesis for the induction of blossom-end rot in tomato fruit. *Annals of Botany*, *95*, 571-581.

Hochmal, A. K., Schulze, S., Trompelt, K. and Hippler, M. (2015). Calcium-dependent regulation of photosynthesis. *Biochimica et Biophysica Acta*, *1847* (9), 993-1003.

Hojjatnooghi, F., Mozafari, V., Tajabadipour, A. and Hokmabadi, H. (2014). Effects of salinity and calcium on the growth and chemical composition of pistachio seedlings. *Journal of Plant Nutrition*, *37*, 928-941.

Hossain, M.M. and Nonami, H. (2012). Effect of salt stress on physiological response of tomato fruit grown in hydroponic culture system. *Horticultural Science, 39*, 26-32.

Huang, J. and Redmann, R. E. (1995). Physiological responses of canola and wild mustard to salinity and contrasting calcium supply. *Journal of Plant Nutrition*, *18* (9), 1931-1949.

Hunt, R. (1978). Plant growth analysis. In R. Hunt, *The Institute of Biology's Studies in Biology No. 96* (pp. 68). London, UK: Edward Arnorld Ltd.

Iglesias, M.J., García-López, J., Collados-Luján, J.F., López-Ortiz, F., Díaz, M., Toresano, F. and Camacho, F. (2015). Differential response to environmental and nutritional factors of high-quality tomato varieties. *Food Chemistry, 176,* 278-287.

Imada, S., Matsuo, N., Acharya, K. and Yamanaka, N. (2015). Effects of salinity on fine root distribution and whole plant biomass of *Tamarix ramosissima* cuttings. *Journal of Arid Environments*, *114*, 84-90.

Ismail, M. R. and Burrage, S. W. (1994). Effects of salinity on growth, water relations and photosynthetic rate of tomatoes grown in nutrient film technique. *Pertanika Journal of Tropical Agricultural Science*, *17*, 73-79.

Iyer, S. and Caplan, A. (1998). Products of proline catabolism can induce osmotically regulated genes in rice. *Plant Physiology*, *116*, 203-211.

Jamil, M., Rehman, S.U. and Rha, E. S. (2014). Response of growth, PSII photochemistryand chlorophyll content to salt stress in four *Brassica* species. *Life Science Journal*, *11*, 139-145.

Jiang, Y. and Huang, B. (2001). Effects of calcium on antioxidant activities and water relations associated with heat tolerance in two cool-season grasses. *Journal of Experimental Botany*, *52*, 341-349.

Johnson, R. W., Dixon, M. A. and Lee, D. R. (1992). Water relations of the tomato fruit during growth. *Plant, Cell and Environment*, *15*, 947-953.

Jose, A., Hernandez, A., Maria, S. and Almansa, B. (2002). Short term effects of salt stress on antioxidant systems and leaf water relations of pea leaves. *Physiologia Plantarum*, *115*, 251-257.

Juan, M., Rivero, R. M., Romero, L. and Ruiz, J. M. (2005). Evaluation of some nutritional and biochemical indicators in selecting salt-resistant tomato cultivars. *Environmental and Experimental Botany*, *54*, 193-201.

Kanayama, Y. and Kochetov, A. (2015). *Abiotic Stress Biology in Horticultural Plants*. Springer, Japan.

Katerji, N., Van Hoorn, J.W., Hamdy, A., Mastrorilli, M. and Mou Karzel, E. (1997). Osmotic adjustment of sugarbeets in response to soil salinity and its influence on stomatal conductance, growth and yield. *Agricultural Water Management*, *34*, 57-69.

Katsuhara, M., Otsuka, T. and Ezaki, B. (2005). Salt stress-induced lipid peroxidation is reduced by glutathione S-transferase, but this reduction of lipid peroxides is not enough for a recovery of root growth in *Arabidopsis*. *Plant Science*, *169*, 369-373.

Kaya, C., Ak, B.E. and Higgs, D. (2003). Response of salt-stressed strawberry plants to supplementary calcium nitrate and/or potassium nitrate. *Journal of Plant Nutrition, 26*, 543-560.

Kaya, C., Kirnak, H., Higgs, D. and Saltali, K. (2002). Supplementary calcium enhances plant growth and fruit yield in strawberry cultivars grown at high (NaCl) salinity. *Scientia Horticulturae, 93*, 65-74.

Khan, M. N., Siddiqui, M. H., Mohammad, F., Naeem, M. and Khan, M. M. A. (2010). Calcium chloride and gibberellic acid protect Linseed (*Linum usitatissimum* L.) from NaCl stress by inducing antioxidative defence system and osmoprotectant accumulation. *Acta Physiologiae Plantarum*, *32*, 121-132.

Khayyat, M., Tafazoli, E., Eshghi, S., Rahemi, M. and Rajaee, S. (2007). Salinity, supplementary calcium and potassium effects on fruit yield and quality of strawberry (*Fragaria ananassa* Duch.). *American-Eurasian Journal of Agricultural and Environmental Sciences*, *2*, 539-544.

Knight, H. (2000). Calcium signalling during abiotic stress in plants. *International Review of Cytology*, *195*, 269-324.

Koca, H., Bor, M., Ödzemir, F. and Türkan, I. (2007). The effect of salt stress on lipid peroxidation, antioxidative enzymes and proline content of sesame cultivars. *Environmental and Experimental Botany, 60,* 344-351.

Koca, H., Ozdemir, F. and Turkan, I. (2006). Effect of salt stress on lipid peroxidation and superoxide dismutase and peroxidase activities of *Lycopersicon esculentum* and *L. pennellii*. *Biologia Plantarum*, *50*, 745-748.

Koushafar, M., Khoshgoftarmanesh, A.H., Moezzi, A. and Mobli, M. (2011). Effect of dynamic unequal distribution of salts in the root environment on performance and Crop Per Drop (CPD) of hydroponic-grown tomato. *Scientia Horticulturae*, *131*, 1-5.

Kreiger, A. and Weiss, E. (1993). The role of calcium in the pH dependent control of photosystem II. *Photosynthesis Research*, *37*, 117-130.

Ksouri, R., Megdiche, W., Debez, A., Falleh, H., Grignon, C. and Abdelly, C. (2007). Salinity effects on polyphenol content and antioxidant activities in leaves of the halophyte *Cakile maritima*. *Plant Physiology and Biochemistry*, *45*, 244-249.

Kurth, E., Cramer, G. R., Läuchli, A. and Epstein, E. (1986). Effects of NaCl and $CaCl_2$ on cell large enlargement and cell production in cotton roots. *Plant Physiology*, *82*, 1102-1106.

Lawlor, D. W. and Cornic, G. (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant, Cell and Environment*, *25*, 275-294.

Liu, D., Jiang, W. and Gao, X. (2004). Effects of cadmium on root growth, cell division and nucleoli in root tips of garlic. *Physiologia Plantarum*, *47*, 79-83.

López-Pérez, L., Martínez-Ballesta, M.C., Maurel, C. and Carvajal, M. (2009). Changes in plasma membrane lipids, aquaporins and proton pump of broccoli roots, as an adaptation mechanism to salinity. *Phytochemistry*, *70*, 492-500.

Lucier, G., Lin, B., Allshouse, J. and Kantor, L. (2002, April 2). Factors affecting tomato consumption in the United States, vegetables and specialities.

Economic Research Service, USDA. Retrieved from http://www.ers.usda.gov/briefing/consumptiongallery/tomatoconsumptionpdf

Lurie, S. and Klein, J. D. (1992). Ripening characteristics of tomatoes stored at 12-degrees-C and 2-degrees-C following a prestorage heat-treatment. *Scientia Horticulturae*, *51*, 55-64.

Lutts, S., Kinet, J. M. and Bouharmont, J. (1996). Effects of salt stress on growth, mineral nutrition and proline accumulation in relation to osmotic adjustment in rice (*Oryza sativa* L.) cultivars differing in salinity resistance. *Plant Growth Regulation*, *19*, 207-218.

Lycoskoufis, 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. *Scientia Horticulturae*, *106*, 147-161.

Lynch, J. and Läuchli, A. (1988). Salinity affects intracellular calcium in corn root protoplasts. *Plant Physiology, 87*, 351–356.

Madani, B., Mohamed, M.T.M., Biggs, A.R., Kadir, J., Awang, Y., Tayebimeigooni, A. and Shojei, T.R. (2014). Effect of pre-harvest calcium chloride applications on fruit calcium level and post-harvest anthracnose disease of papaya. *Crop Protection, 55*, 55-60.

Madea, Y., Yoshiba, M. and Tadano, T. (2005). Comparison of Ca effect on the salt tolerance of suspension cells and intact plants of tobacco (*Nicotiana tobacum* L., cv. Bright Yellow-2). *Soil Science and Plant Nutrition*, *51*, 313-318.

Magan, J. J., Gallardo, M., Thompson, R. B. and Lorenzo, P. (2008). Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions. *Agricultural Water Management*, *95*, 1041-1055.

Maggio, A., De Pascale, S., Angelino, G., Ruggiero, C. and Barbieri, G. (2004). Physiological response of tomato to saline irrigation in long-term salinized soils. *European Journal of Agronomy*, *21*, 149-159.

Maggio, A., Hasegawa, P.M., Bressan, R.A., Consiglio, M.F. and Joly, R.J. (2001). Unraveling the fuctional relationship between root anatomy and stress tolerance. *Australian Journal of Plant Physiology, 28* (10), 999-1004.

Maggio, A., Raimondi, G., Martino, A. and Pascale, S.D. (2007). Salt stress response in tomato beyond the salinity tolerance threshold. *Environmental and Experimental Botany*, *59*, 276-282.

Mahajan, S. and Tuteja, N. (2005). Cold, salinity and drought stresses: An overview. *Archives of Biochemistry and Biophysics*, *444*, 139-158.

Mahajan, S., Pandey, G.K. and Tuteja, N. (2008). Calcium-and salt-stress signaling in plants: Shedding light on SOS pathway. *Archives of Biochemistry and Biophysics, 471*, 145-158.

Malash, N., Ghaibeh, A., Yeo, A., Ragab, R. and Cuatero, J. (2002). Effect of irrigation water salinity on yield and fruit quality of tomato. *Acta Horticulturae*, *673*, 415-423.

Manaa, A., Gharbi, E., Mimouni, H., Wasti, S., Aschi-Smiti, S., Lutts, S. and Ben Ahmad, H. (2014). Simultaneous application of salicylic acid and calcium improves salt tolerance in two contrasting tomato (*Solanum lycopersicum*) cultivars. *South African Journal of Botany*, *95*, 32-39.

Marcelis, L. F. M. and VanHooijdonk, J. (1999). Effect of salinity on growth, water use and nutrient use in radish (*Raphanus sativus* L.). *Plant Soil*, *215*, 57-64.

Marinova, D., Ribarova, F. and Atanassova, M. (2005). Total phenolics and total flavonoids in Bulgarian fruits and vegetables. *Journal of the University of Chemical Technology and Metallurgy*, *40*, 255-260.

Marschner, H. (1995). *Mineral nutrition of higher plants*. London : Academic Press.

Mathieu, C. and Pieltain, F. (2003). Analyse chimique des sols, mĕthodes choisies. *Lavoisier Tec et Doc, Paris*, p. 388.

Melgar, J.C., Benlloch, M. and Fernández-Escobar, R. (2006). Calcium increases sodium exclusion in olive plants. *Scientia Horticulturae, 109,* 303-305.

Mengel, K., Kirkby, E. A., Kosegarten, H. and Appel, T. (2001). *Principles of Plant Nutrition.* London: Kluwer Academic Publishers.

Miranda, D., Fischer, G., Mewis, I., Rohn, S. and Ulrichs, C. (2014). Salinity effects on proline accumulation and total antioxidant activity in leaves of the cape gooseberry (*Physalis peruviana* L.). *Journal of Applied Botany and Food Quality*, *87*, 67-73.

Munns, R. (2002). Comparative physiology of salt and water stress. *Plant, Cell and Environment*, *25*, 239-250.

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

Munns, R., Schachtman, D. P. and Condon, A. G. (1995). The significance of a two-phase growth response to salinity in wheat and barley. *Australian. Journal of Plant Physiology, 22*, 561–569.

Murillo-Amador, B., Jones, H.G., Kaya, C., Aguilar, R.L., García-Hernández, J.L., Troyo-Diéguez, E., Avilo-Serrano, N.Y. and Rueda-Puente, E. (2006). Effects of foliar application of calcium nitrate on growth and physiological attributes of cowpea (*Vigna unguiculata* L. Walp.) grown under salt stress. *Environmental and Experimental Botany, 58,* 188-196.

Naeem, M.S., Jin, Z.L., Wan, G.L., Liu, D., Liu, H.B., Yoneyama, K. and Zhou, W.J. (2010). 5-Aminolevulinic acid improves photosynthetic gas exchange capacity and ion uptake under salinity stress in oilseed rape (*Brassica napus* L.) *Plant Soil*, *332*, 405-415.

Navarro, J. M., Martinez, V. and Carvajal, M. (2000). Ammonium bicarbonate and calcium effects on tomato plants grown under saline conditions. *Plant Science*, *157*, 89-96.

Nazarbeygi, E., Yazdi, H. L., Naseri, R. and Soleimani, R. (2011). The effects of different levels of salinity on proline and *a* and *b* chlorophylls in canola. *American-Eurasian Journal of Agricultural and Environmental Sciences*, *10* (1), 70-74.

Nemati, I., Moradi, F., Gholizadeh, S., Esmaeili, M.A. and Bihamta, M.R. (2011). The effect of salinity stress on ions and soluble sugars distribution in leaves, leaf sheaths and roots of rice (*Oryza sativa* L.) seedlings. *Plant, Soil and Environment, 57*, 26-33.

Neumann, P. M., Volkenburgh, E. V. and Cleland, R. E. (1988). Salinity stress inhibits bean leaf expansion by reducing turgor not wall extensibility. *Plant Physiology*, *88*, 233-237.

Nonami, H., Fukuyama, T., Yamamoto, M., Yang, L. and Hashimoto, Y. (1995). Blossom-end rot of tomato plants may not be directly caused by calcium deficiency. *Acta Horticulturae*, *396*, 107-114.

Parida, A. K. and Das, A. B. (2005). Salt tolerance and salinity effects on plants: a review. *Ecotoxicology and Environmental Safety*, *60*, 324-349.

Patel, N.T., Vaghela, P.M., Patel, A.D. and Pandey, A.N. (2011). Implications of calcium nutrition on the response of *Caesalpinia crista* (Fabaceae) to soil salinity. *Acta Ecologica Sinica*, *31*, 24-30.

Perera, L. K. K. R., Mansfield, T. A. and Malloch, A. J. C. (1994). Stomatal responses to sodium ions in *Aster tripolium*: a new hypothesis to explain salinity regulation in above-ground tissues. *Plant, Cell and Environment*, *17*, 335-340.

Perez, M.L.S., Paris, J.L.C., Yasuda, R.S. and Lao, M.T. (2009). Influence of salinity and fertilization level on the nutrient distribution in tomato plants under a polyethylene greenhouse in the Mediterranean area. C*ommunications in Soil Science and Plant Analysis, 40,* 498-513.

Perez-Alfocea, F. and Larher, F. (1995). Effects of phlorizin and p-chloromercuribenzenesulfonic acid on sucrose and proline accumulation in detached tomato leaves submitted to NaCl and osmotic stress. *Journal of Plant Physiology*, *145*, 106-111.

Perez-Alfocea, F., Balibrea, M. E., Santa Cruz, A. and Estan, M. T. (1996). Agronomical and physiological characterization of salinity tolerance in a commercial tomato hybrid. *Plant and Soil*, *180*, 251-257.

Pokorny, J. (2001). Introduction. In J. Pokorny, N. Yanishlieva and M. H. Gordon (Eds.), *Antioxidants in Food: Practical Applications (*pp. 1-3). Cambridge: Woodhead Publishing Limited.

Ranganna, S. (1986). *Handbook of analysis and quality control for fruit and vegetable products*. New Delhi: McGraw-Hill.

Rao, A.V. and Agarwal, S. (2000). Role of antioxidant lycopene in cancer and heart disease. *Journal of American College of Nutrition, 19*, 563-569.

Rao, G. G. and Rao, G. R. (1981). Pigment composition and chlorophyllase activity in pigeon pea (*Cajamus indicus Spreng*) and Gingelley (*Sesamum indicum* L.) under NaCl salinity. *Indian Journal of Experimental Biology*, *19*, 768-770.

Rengel, Z. (1992). The role of calcium in salt toxicity. *Plant, Cell and Environment*, *15*, 625-632.

Rezazadeh, A., Ghasemnezhad, A., Barani, M. and Telmadarrehei, T. (2012). Effect of salinity on phenolic composition and antioxidant activity of artichoke (*Cynara scolymus* L.) leaves. Research *Journal of Medicinal Plants*, *6*, 245-252.

Rivero, R. M., Mestre, T. C., Mittler, R., Rubio, F., Garcia-Sanchez, F. and Martinez, V. (2014). The combined effect of salinity and heat reveals a specific physiological, biochemical and molecular response in tomato plants. *Plant, Cell and Environment*, *37*, 1059-1073.

Robinson, W. B. (1949). The effect of sunlight on the ascorbic acid content of strawberries. *Journal of Agricultural Research*, *78*, 257-262.

Rubio, J. S., Garcia-Sanchez, F., Rubio, F. and Martinez, V. (2009). Yield, blossom-end rot incidence, and fruit quality in pepper plants under moderate salinity are affected by K^+ and Ca^{2+} fertilization. *Scientia Horticulturae*, *119*, 79-87.

Safeena, M. I. S., Bandara, D. C. and Sumanasinghe, V. A. (2002). Effect of salt stress on leaf area, rate of photosynthesis and proline accumulation of rice varieties at different growth stages. *Tropical Agricultural Research*, *14*, 87-96.

Sairam, R. K. and Srivastava, G. C. (2002). Changes in antioxidant activity in sub-cellular fractions of tolerant and susceptible wheat genotypes in response to long term salt stress. *Plant Science*, *162*, 897-904.

Saito, T., Matsukura, C., Ban, Y., Shoji, K., Sugiyama, M., Fukuda, N. and Nishimura, S. (2008). Salinity stress affects assimilate metabolism at the gene-expression level during fruit development and improves fruit quality in tomato (*Solanum lycopersicum* L.). *Journal of the Japanese Society for Horticultural*, *77*, 61-68.

Sakamoto, M., Munemura, I., Tomita, R. and Kobayashi, K. (2008). Involvement of hydrogen peroxide in leaf abscission signalling, revealed by analysis with an in vitro abscission system in *Capsicum* plants. *The Plant Journal*, *56*, 13-27.

Sanchez, M.C., Valencia, C., Ciruelos, A., Lattore, A. and Gallegos, C. (2003). Rheological properties of tomato paste: Influence of the addition of tomato slurry. *Journal of Food Science, 68*, 551-554.

Sangtarashani, E. S., Tabatabaei, S. J. and Bolandnazar, S. (2013). Yield, photosynthetic efficiency and quality parameters of cherry tomato as affected by Ca^{2+} and K^{+} under NaCl salinity. *International Journal of Agriculture and Crop Sciences*, *5* (12), 1280-1288.

Sankar, P.D., Saleh, M.A.A.M. and Selvaraj, C.I. (2011). Rice breeding for salt tolerance. *Research in Biotechnology, 2*, 1-10.

Santos, C. V. (2004). Regulation of chlorophyll biosynthesis and degradation by salt stress in sunflower leaves. *Scientia Horticulturae*, *103*, 93-99.

Sato, S., Sakaguchi, S., Furukawa, H. and Ikeda, H. (2006). Effects of NaCl application to hydroponic nutrient solution on fruit characteristics of tomato (*Lycopersicon esculentum* Mill.). *Scientia Horticulturae, 109*, 248-253.

Saure, M.C. (2001). Blossom-end rot of tomato (*Lycopersicon esculentum* Mill.) – a calcium or a stress related disorder? *Scientia Horticulturae*, *90*, 193-208.

Savvas, D. and Lenz, F. (2000). Effects of NaCl or nutrient-induced salinity on growth, yield and composition of eggplants grown in rockwool. *Scientia Horticulturae*, *84*, 37-47.

Savvas, D., Giotis, D., Chatzieustratiou, E., Bakea, M. and Patakioutas, G. (2009). Silicon supply in soilless cultivations of zucchini alleviates stress induced by salinity and powdery mildew infections. *Environmental and Experimental Botany*, *65*, 11-17.

Schatchman, D. and Liu, W. (1999). Molecular pieces to the puzzle of the interaction between potaasium and sodium uptake in plants. *Trends in Plant Science*, *4*, 281-287.

Selmar, D. and Mohamed, A. A. (2007). Potential of salt stress and drought to increase pharmaceutical significant secondary compounds in plants. *Agriculture and Forestry Research*, *58*, 139-144.

Sevengor, S., Yasar, F., Kusvuran, S. and Ellialtioglu, S. (2011). The effect of salt stress on growth, chlorophyll content, lipid peroxidation and antioxidative enzymes of pumpkin seedling. *African Journal of Agricultural Research, 6*, 4920-4924.

Sgherri, C., Navari-Izzo, F., Pardossi, A., Soressi, G. P. and Izzo, R. (2007). The influence of diluted seawater and ripening stage on the content of antioxidants in fruits of different tomato genotypes. *Journal of Agricultural and Food Chemistry*, *55*, 2452-2458.

Shabala, S. and Newman, I. (2000). Salinity effects on the activity of plasma membrane H^+ and Ca^{2+} transporters in bean leaf mesophyll: masking role of the cell wall. *Annals of Botany*, *85*, 681-686.

Shalata, A. and Tal, M. (1998). The effect of salt stress on lipid peroxidation and antioxidants in the of the cultivated tomato and its wild salt-tolerant relative *Lycopersicon pennellii*. *Physiologia Plantarum*, *104*, 169-174.

Shiam, I. H., Nahiyan, A. S. M., Momena, K., Mehraj, H. and Jamal Uddin, A. F. M. (2015). Effect of NaCl salt on vegetative growth and yield of sixteen tomato lines. *Journal of Bioscience and Agriculture Research*, *03*, 15-27.

Shiyab, S. (2011). Effects of NaCl application to hydroponic nutrient solution on macro and micro elements and protein content of hot pepper (*Capsicum annuum* L.). *Journal of Food, Agriculture, and Environment*, *9*, 350-356.

Shoresh, M., Spivak, M. and Bernstein, N. (2011). Involvement of calcium-mediated effects on ROS metabolism in the regulation of growth improvement under salinity. *Free Radical Biology and Medicine*, *51*, 1221-1234.

Singh, A. K. and Dubey, R. S. (1995). Changes in chlorophyll *a* and *b* contents and activities of photosystems 1 and 2 in rice seedlings induced by NaCl. *Photosynthetica*, *31*, 489-499.

Sivritepe, N. and Eris, A. (1999). Determination of salt tolerance in some grapevine cultivars (*Vitis vinifera* L.) under in vitro conditions. *Turkish Journal of Biology*, *23* (4), 473-485.

Smith, S. (1992). *Greenhouse Gardener's Companion (Revised and Expanded). Growing Food and Flowers in Your Greenhouse or Sunspace*. Golden, Colorado: Fulcrum Publishing.

Stamatakis, A., Papadantonakis, N., Lydakis-Simantiris, N., Kefalas, P. and Savvas, D. (2003). Effects of silicon and salinity on fruit yield and quality of tomato grown hydroponically. *Proc. IS on Greenhouse Salinity* Eds: A. Pardossi et al. Acta Hort 609.

Stewart, G. R. and Lee, J. A. (1974). The role of proline accumulation in halophytes. *Planta (Berl.)*, *120*, 279-289.

Suarez, D. L. and Lebron, I. (1993). Water quality criteria for irrigation with high saline water. In H. Leith and A. Al-Massom (Eds.), *Towards the Rational Use of High Salinity Tolerant Plants* (pp. 389-397). The Netherlands: Kluwer Academic Publ.

Sudhir, P. and Murthy, S. D. S. (2004). Effects of salt stress on basic processes of photosynthesis. *Photosynthetica*, *42*, 481-486.

Swamy, P. M. and Reddy, C. V. S. (1991). Amelioration of NaCl salinity stress by calcium chloride: lipid peroxidation, superoxide dismutase and catalase activities. *Proceedings of the Indian National Science Academy*, *57* (3, 4), 267-269.

Taffouo, V. D., Nouck, A. H., Dibong, S. D. and Amougou, A. (2010). Effects of salinity stress on seedlings growth, mineral nutrients and total chlorophyll of some tomato (*Lycopersicon esculentum* L.) cultivars. *African Journal of Biotechnology*, *9* (33), 5366-5372.

Taïbi, K.H., Taïbi, F. and Belkhodja, M. (2012). Effects of external calcium supply on the physiological response of salt stressed bean (*Phaseolus vulgaris* L.). *Genetics and Plant Physiology*, *2* (3-4), 177-186.

Tayebimeigooni, A., Awang, Y., Mahmood, M., Selamat, A. and Wahab, Z. (2012). Leaf water status, proline content, lipid peroxidation and accumulation of hydrogen peroxide in salinized Chinese kale (*Brassica alboglabra*). *Jornal of Food, Agriculture and Environment*, *10,* 371-374.

Tayebi-Meigooni, A., Awang, Y., Puteh, A., Madani, B. And Khalatbari, A. (2014). Growth performance and ionic composition of Chinese kale (*Brassica oleracea* var. *alboglabra* L.) plants grown under saline conditions. *Journal of Food, Agriculture and Environment*, *12*, 307-313.

Taylor, M. D. and Locascio, S. J. (2004). Blossom end rot: A calcium deficiency. *Journal of Plant Nutrition*, *27* (1), 123-139.

Thompson, J. E., Legge, R. L. and Barber, R. F. (1987). The role of free radicals in senescence and wounding. *New Phytologist*, *105*, 314-317.

Tonucci, L., Holden, J., Beecher, G., Khackik, F., Davis, C. and Mulokozi, G. (1995). Carotenoid content of thermally processed tomato-based food products. *Journal of Agricultural and Food Chemistry*, *43*, 579-586.

Toor, R.K. and Savage, G.P. (2005). Antioxidant activity in different fractions of tomatoes. *Food Research International, 38*, 487-494.

Tuna, A. L. (2014). Influence of foliarly applied different triazole compounds on growth, nutrition, and antioxidant enzyme activities in tomato (*Solanum lycopersum* L.) under salt stress. *Australian Journal of Crop Science*, *8* (1), 71-79.

Tuna, A. L., Burun, B., Altunlu, H., Altan, F., Kaya, C. and Yokas, I. (2008). Responses of the tomato (*Lycopersicon esculentum* Mill.) plant to exposure to different salt forms and rates. *Turkish Journal of Agriculture and Forestry*, *32*, 319-329.

Tuna, A.L., Kayab, C., Ashraf, M., Altunlu, H., Yokas, I. and Yagmur, B. (2007). The effects of calcium sulphate on growth, membrane stability and nutrient uptake of tomato plants grown under salt stress. *Environmental and Experimental Botany, 59*, 173-178.

Upreti, K.K. and Murti, G.S.R. (2010). Response of grape rootstocks to salinity: changes in root growth, polyamines and abscisic acid. *Biologia Plantarium*, 54 (4), 730-734.

Voogt, W. and Sonneveld, C. (1997). Nutrient management in closed growing systems for greenhouse production. In E. Goto, K. Kurata, M. Hayashi and S. Sase (Eds.), *Plant Production in Closed Ecosystems* (pp. 83-102). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Wang, W., Vinocur, B. and Altman, A. (2003). Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. *Planta*, *218*, 1-14.

Weatherly, P. E. (1950). Studies in the water relations of cotton 1. The field measurement of water deficits in leaves. *New Phytologist*, *49*, 81-97.

White, P. J. (1998). Calcium channels in the plasma membrane of roots cells. *Annals of Botany*, *81*, 173-183.

White, P. J. (2000). Calcium channels in higher plants. *Biochimica et Biophysica Acta*, *1465*, 171-189.

White, P. J. and Broadley, M. R. (2003). Calcium in plants. *Annals of Botany*, *92*, 487-511.

Wong, S. P. Lai, P. L. and Jen, H. W. K. (2005). Antioxidant activities of aqueous extracts of selected plant. *Food Chemistry*, *99*, 775-783.

Yasar, F., Ulzal, O., Tufenkci, S. and Yildiz, K. (2006). Ion accumulation in different organs of green bean genotypes grown under salt stress. *Plant, Soil and Environment*, *52*, 476-480.

Yeo, A.R. (1998). Molecular biology of salt tolerance in the context of whole-plant physiology. *Journal of Experimental Botany, 49* (323), 915-929.

Yeo, A.R. (1994). Physiological criteria in screening and breeding. In A. R. Yeo and T. J. Flowers (Eds.), *Soil Mineral Stresses, Approaches to Crop Improvement* (pp. 37–60). Berlin: Springer-Verlag.

Yeo, A.R., Lee, K.S., Izard, P., Boursier, P.J. and Flowers, T.J. (1991). Short and long term effects of salinity on leaf growth in rice (*Oriza sativa* L.). *Journal of Experimental Botany*, *42*, 881-889.

Yokas, I., Tuna, A.L., Burun, B., Altunlu, H., Altan, F. and Kaya, C. (2008). Responses of tomato (*Lycopersicon esculentum* Mill.) plant to exposure to different salt forms and rates. *Turkish Journal of Agriculture and Forestry*, *32*, 319-329.

Zhang, K., Guo, N., Lian, L., Wang, J., Lv, S. *and* Zhang, J. (2011). Improved salt tolerance and seed cotton yield in cotton (*Gossypium Hirsutum* L.) by transformation with beta gene for glycinebetaine synthesis. *Euphytica, 181*, 1–16.

Zhong, H. and Läuchli, A. (1993). Changes of cell wall composition and polymer size in primary roots of cotton seedlings under salt stress. *Journal of Experimental Botany*, *44*, 773-778.

Zhu, J. K. (2003). Regulation of ion homeostasis under salt stress. *Current Opinion in Plant Biology*, *6*, 441-445.

Zhu, J., Gong, Z., Zhang, C., Song, C.P., Damsz, B., Inan, G., Koiwa, H., Zhu, J.K., Hasegawa, P.M. and Bressan, R.A. (2002). OSM1/SYP61: a syntaxin protein in Arabidopsis controls abscisic-mediated and non-abscisic acid-mediate responses to abiotic stress. *Plant Cell*, *14*, 3009-3028.

Zhu, J.K. 2007. *Plant salt stress*. USA: Wiley & Sons.