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Interactive Effects of Drought Stress and Ozonated Water on Growth and Yield of Cucumber (*Cucumis sativus* L.)

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ABSTRACT

In order to investigate the effect of drought stress and ozone on some properties of cucumber, a factorial experiment with complete randomized design was carried out in greenhouse at Khorasgan University, Isfahan, Iran in 2014. Experimental treatments were drought stress including three levels 100% (control), 80% (mild stress) and 60% of field capacity (severe stress) and three ozone concentrations in irrigation water (0, 0.5 and 1 ppm). After germination, cucumber seeds were grown in pots containing soil, cocopeat and perlite and fed with Hoagland solution and were imposed with drought stress and ozone treatments. The fruit weight per pot, stem thickness, ash weight, number of leaf and weight of root (fresh and dry) were determined. The results showed that across the ozone concentrations, drought stress significantly reduced fruit weight, leaf number, dry and fresh weight of root. Also, across the levels of drought stress, statistical testing showed a significant increase in fruit weight with increasing ozone concentrations. However, the highest (91.51 g) fruit weight was obtained at the third level of ozonated water (1 ppm) and 100% FC and for stem thickness (10.2 mm) was 60% FC and without ozone. The highest leaf number (48), fresh weight (6.22 g) and dry weight (2.62 g) of root was revealed at the 0.5 ppm ozone and 100% FC.

Key words: Cucumber, drought stress, greenhouse, ozonated water

INTRODUCTION

Water is one of the most important environmental factors that affect the plant growth (Wagner, 1993). Drought stress is a major factor responsible for the limited growth of plants and reduced photosynthesis and consequently led to reduction of crop production (Efeoglu *et al*., 2009). This factor is most difficult to tackle because of the major link between photosynthesis and transpiration (Posch and Bennett, 2009). Under drought stress condition, crop management practices that improve drought stress resistance may benefit plant growth (Egilla *et al*., 2001). Water deficit reduced growth rate, net photosynthetic rate and transpiration rate (Li *et al*., 2009). Subramanian *et al*. (2006) reported that the drought stress significantly decreased plant height, number of primary branches and flower and fruit production of tomato plants.

Ozone (O_3) has been used to control growth of microorganism, food and drinking water treatment (Wang *et al*., 2006), treatment of fruits and vegetables to increase shelf-life of the products (Guzel-Seydim *et al*., 2004). Also, ozone had a potential for enhancing crop yield (Zheng *et al*., 2007). In a greenhouse experiment, Chan *et al*. (2007) concluded that irrigation by ozonated water for one month increased the leaf area and fresh weight of Pak Choi and Chinese spinach. However, Graham *et al*. (2011b) reported that single applications of aqueous ozone had no effect on leaf area and shoot dry weight. However, pathogen levels were significantly reduced in all treatments aqueous ozone. Ohashi-Kaneko *et al*. (2009) suggested that ozonated water can be to sterilize of different source water in order to control pathogens during the early growth stage of plants.

Cucumber (*Cucumis sativus* L.) is one of the most popular greenhouse vegetables due to high economic and nutritious value in Iran. Studies demonstrated that this plant needs more water than normal grain crops (Li *et al*., 2000). Over the last decades, the rapid development of greenhouse vegetable planting would increase water infrequency.

The effects of drought stress (Subramanian *et al*., 2006; Li *et al*., 2011) and ozonated water (Ohashi-Kaneko *et al*., 2009; Graham *et al*., 2011a) on the growth and productivity of vegetables have been studied separately by several researchers, but the interactive impacts of ozone and drought stress on cucumber are not yet available in the literature. Thus, this study aims to investigate combined ozone and drought stress effects on: fruit weight, stem thickness, ash weight, number of leaf and root weight (fresh and dry) of cucumber.

MATERIALS AND METHODS

Experimental design: In order to evaluate the effects of drought stress and ozone on some properties of cucumber a greenhouse experiment was conducted in Khorasgan University in 2014. Soil analysis results are shown in Table 1. The soil belongs to the non-saline soil with a neutral reaction and the amount of lime which is relatively high. Average temperature of day and night were 26 and 18°C, respectively, in greenhouse. Cucumber (*Cucumis sativus* L.) seeds were sowed in a box of cocopeat substrate and young plants at four leaf stages were transferred in 10 L pots filled with soil (80%) and leca+perlite (20%). One cucumber plant was cultivated per pot. Modified Hoagland solution was used for fertigation of the pots. Electrical conductivity of nutrient solution was 1.5 dS m^{-1}. pH of the this solution was set at 5.6 with nitric acid. Experimental treatments were drought stress including three levels 100% (control), 80% (mild stress) and 60% of field capacity (severe stress) and three ozone concentrations in irrigation water (0, 0.5 and 1 ppm). The nine treatment combinations were replicated five times and arranged in a randomized complete block design. Ozonated water was generated with an electrolytically ozonated water generator. The plants were exposed to ozone concentrations via irrigation with nutrient solution. For preparation of 0.5 and 1 ppm O_3, ozone was added to nutrient solution for 5 and 10 sec, respectively.

Table 1: Some chemical and physical properties of experimental field soil

Properties	Values
EC (dS m^{-1})	1.42
pH	8.22
N (%)	0.08
P (mg kg^{-1})	28
K (mg kg^{-1})	153
OC (%)	1.7
CEC (cmol kg^{-1})	19
$CaCO_3$ (%)	42
Texture	Sandy loam
ρb (g cm^{-3})	1.5
Porosity (%)	56

EC: Electrical conductivity, OC: Organic carbon, CEC: Cation exchange capacity, ρb: Bulk density

Plant analysis: Some growth indices including of fruit weight, stem thickness, ash weight, number of leaf, fresh and dry weight of root were determined at the end of growth period. The fruit weight, ash weight, fresh and dry weight of root were determined by weighting theses in the air on a precision digital balance with an accuracy of 0.001 g. The stem thickness was measured with a digital vernier caliper.

Soil analysis: Soil pH was measured in the soil saturation paste and Electrical Conductivity (EC) in saturated extracts. Total OC (the Walkley and Black method), total nitrogen (the Kejldahl method), available K (with ammonium acetate), available P (the Olsen's method) and Cation Exchange Capacity (CEC) with NH_4OAc method were determined via procedures described in Baruah and Barthakur (1997). The amounts of $CaCO_3$ were determined using the methods suggested by USDA (1992). Soil texture was performed using the hydrometer method (Gee and Bauder, 1986). Soil bulk density extracted by volumetric cylinder (Lestariningsih *et al*., 2013).

Statistical analysis: The effects of ozonated water and drought stress on plant properties were determined by two-way analysis of variance (ANOVA). When statistical significance was found ($p \leq 0.05$), comparison of the means was carried out by using the Duncan test. All statistical procedures were carried out using the software package SAS 9.1 for Windows.

RESULTS

Fruit weight: The results showed that across the ozone concentrations, drought stress significantly reduced fruit weight. Also, across the levels of drought stress, statistical testing showed a significant increase in fruit weight with increasing ozone concentrations (Fig. 1). However, the highest fruit weight was obtained at the third level of ozonated water (1 ppm) and 100% FC (Fig. 1).

Stem thickness: As shown in Fig. 2, the stem thickness of plant in control treatment (0 ppm O_3) increased with increase in levels of drought stress. The highest stem thickness, fresh and dry weight of root was revealed at the 0.5 ppm ozone and 100% FC (Fig. 2). However, no clear pattern in stem thickness was observed in different treatments (Fig. 2).

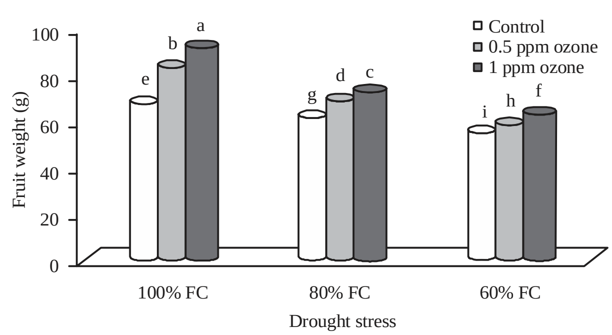

Fig. 1: Effects of ozone concentrations and drought stress on fruit weight of cucumber. Means followed by the same letters are not significantly different at p<0.05, according to the Duncan test

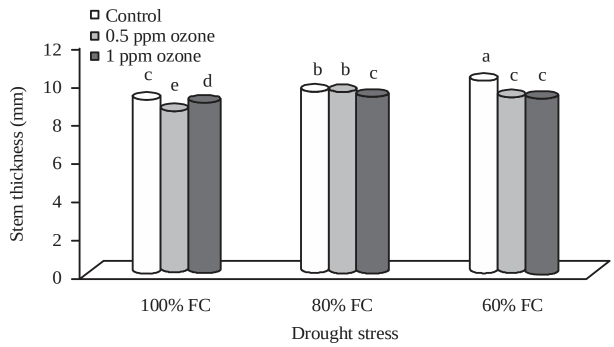

Fig. 2: Effects of ozone concentrations and drought stress on stem thickness of cucumber. Means followed by the same letters are not significantly different at p<0.05, according to the Duncan test

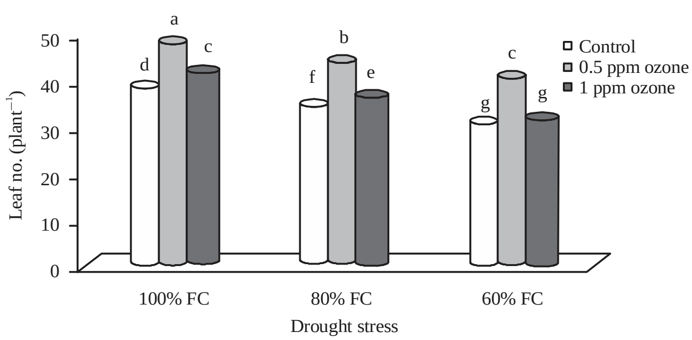

Fig. 3: Effects of ozone concentrations and drought stress on leaf number of cucumber. Means followed by the same letters are not significantly different at p<0.05, according to the Duncan test

Leaf number: The results showed that across the ozone concentrations, drought stress significantly reduced leaf number (Fig. 3). At each drought stress level, highest leaf number was obtained at the 0.5 ppm ozone. In addition, the highest leaf number was revealed at the 0.5 ppm ozone and 100% FC (Fig. 3).

Plant ash weight: Although, the 100 and 80% FC treatments did not differ in plant ash weight there was a significant decrease in plant ash weight in the 60% FC compared to the 80% FC treatment (Fig. 4). However, the results showed that the differences between three ozonated water levels were not significant (Fig. 4).

Dry weight of root: The results showed that drought stress reduced dry weight of root (Fig. 5). At each drought stress level, highest dry weight of root was obtained at the 0.5 ppm ozone. Generally, the highest dry weight of root was revealed at the 0.5 ppm ozone and 100% FC (Fig. 5).

Fresh weight of root: As shown in Fig. 6, drought stress reduced fresh weight of root, however, in some cases, the differences were not (p>0.05) or marginally significant (Fig. 6). At

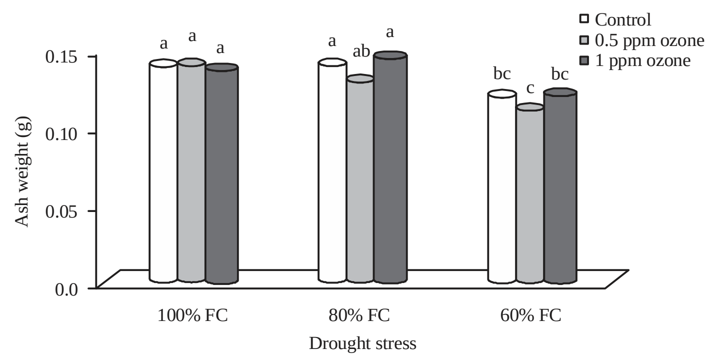

Fig. 4: Effects of ozone concentrations and drought stress on plant ash weight. Means followed by the same letters are not significantly different at p<0.05, according to the Duncan test

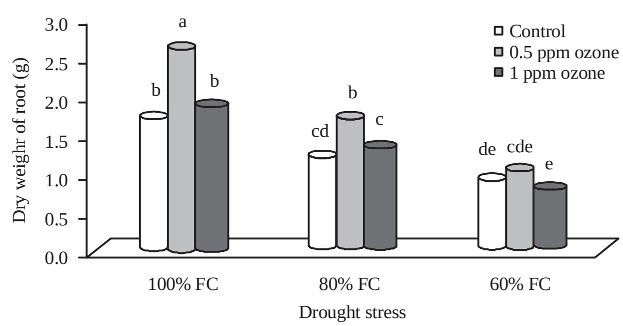

Fig. 5: Effects of ozone concentrations and drought stress on dry weight of root. Means followed by the same letters are not significantly different at p<0.05, according to the Duncan test

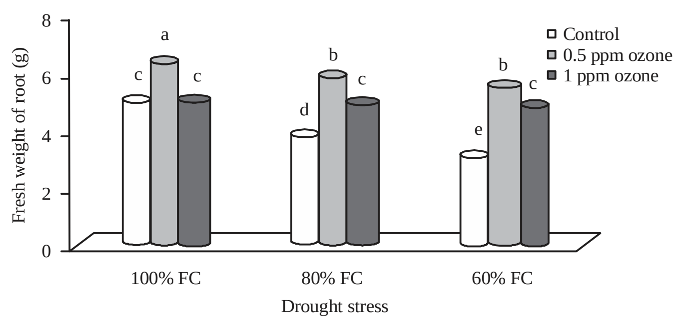

Fig. 6: Effects of ozone concentrations and drought stress on fresh weight of root. Means followed by the same letters are not significantly different at p<0.05, according to the Duncan test

each drought stress level, highest fresh weight of root was obtained at the 0.5 ppm ozone. Generally, the highest fresh weight of root was revealed at the 0.5 ppm ozone and 100% FC (Fig. 6).

DISCUSSION

This study indicated that application of ozone concentration increased the some properties of cucumber plant. These results are agreed with the findings of Ohashi-Kaneko *et al*. (2009), who found that flower bud number, flower number, shoot fresh weight and shoot and root dry weight were greater of tomatoes treated with ozonated water (1.5 ppm concentration) than for control. Also, Chan *et al*. (2007) reported that irrigation by ozonated water increased the leaf area and fresh weight of Pak Choi and Chinese spinach. Graham *et al*. (2011a) demonstrated that stem thickness of tomatoes increase in the 3 ppm treatment compared to the control. Ozone in solution automatically reverts to diatomic oxygen (O_2) through complex decomposition mechanisms (Gottschalk *et al*., 2000; Beltran, 2004). The root respiration by ozonated water might be related to increased biomass productivity of cucumber plants. According to the study on the tomato reported by Ohashi-Kaneko *et al*. (2009), ozonated water did not harm plants but did promote their growth. Sterilization by ozonated water might have decreased root rot, consequently increase water and mineral uptake by plant root (Ohashi-Kaneko *et al*., 2009). However, Graham *et al*. (2011b) reported that single applications of aqueous ozone had no effect on leaf area and shoot dry weight. Jaoude *et al*. (2008) reported that a low level of ozone concentration reduced the number of leaves, flowers and pods, leaf area and dry matter of soybean crops. Li *et al*. (2011) concluded that drought stress decreased growth indexes of cucumber. It is well known that photosynthesis is one of the most sensitive physiological processes that respond to water deficit (Pinheiro and Chaves, 2011). Ismail and Phizackerley (2009) concluded that water deficit reduced fruit yield of tomato up to 18-33%. Panahyan-e-Kivi *et al*. (2009) reported that irrigation water deficit led to the significantly decrease in grain number, grain weight, grain yield and harvest index of lentil genotypes. In a hydroponics condition, Bahavar *et al*. (2009) found that water deficit stress led to the decrease in leaf number of chickpea. Davidson *et al*. (1992) found that water deficit reduced weight of root in the control treatment, but at higher ozone dose this effect was lost, or even reversed. The reduction of plant growth due to water deficit decreased with increasing ozone concentrations.

CONCLUSION

In summary, propose that ozonated water can be to use for irrigation of cucumber plant. Moreover, ozonated water did not harm plants. Overall, the use of ozonated water could provide a useful tool to improve fruit yield of cucumber under drought stress.

REFERENCES

Bahavar, N., A. Ebadi, A. Tobeh and Sh. Jamaati-e-Somarin, 2009. Effects of nitrogen application on growth of irrigated chickpea (*Cicer arietinum* L.) under drought stress in hydroponics condition. Res. J. Environ. Sci., 3: 448-455.

Baruah, T.C. and H.P. Barthakur, 1997. A Textbook of Soil Analysis. Vikas Publishing, New Delhi, India, Pages: 282.

Beltran, F.J., 2004. Ozone Reaction Kinetics for Water and Wastewater Systems. Lewis Publishers, New York.

Chan, G.Y.S., Y. Li, E.K.H. Lam, C.Y. Chen and L. Lin *et al*., 2007. Effects of ozonated water on antioxidants and phytomorores level of vegetables. Proceedings of the IOA Conference and Exhibition Valencia, October 29-31, 2007, Spain, pp: 1-15.

Davidson, S.R., M.R. Ashmore and C. Garretty, 1992. Effects of ozone and water deficit on the growth and physiology of *Fagus sylvatica*. Forest Ecol. Manage., 51: 187-193.

Efeoglu, B., Y. Ekmekci and N. Cicek, 2009. Physiological responses of three maize cultivars to drought stress and recovery. South Afr. J. Bot., 75: 34-42.

Egilla, J.N., F.T. Davies Jr. and M.C. Drew, 2001. Effect of potassium on drought resistance of *Hibiscus rosa-sinensis* cv. Leprechaun: Plant growth, leaf macro- and micronutrient content and root longevity. Plant Soil, 229: 213-224.

Gee, G.W. and J.W. Bauder, 1986. Particle-Size Analysis. In: Methods of Soil Analysis Part 1: Physical and Mineralogical Methods, Klute, A. (Eds.). 2nd Edn. American Society of Agronomy, Madison, WI., USA., pp: 383-411.

Gottschalk, C., J.A. Libra and A. Saupe, 2000. Ozonation of Water and Waste Water: A Practical Guide to Understanding Ozone and its Applications. Wiley, New York.

Graham, T., P. Zhang and M. Dixon, 2011a. Aqueous ozone in the root zone: Friend or foe? J. Horticult. Forest., 3: 58-62.

Graham, T., P. Zhang, E. Woyzbun and M. Dixon, 2011b. Response of hydroponic tomato to daily applications of aqueous ozone via drip irrigation. Sci. Hortic., 129: 464-471.

Guzel-Seydim, Z.B., A.K. Greeneb and A.C. Seydim, 2004. Use of ozone in the food industry. Lebensm. Wiss. Technol., 37: 453-460.

Ismail, M.R. and S. Phizackerley, 2009. Effects of partial rootzone and controlled deficit irrigation on growth, yield and peroxidase activities of tomatoes (*Lycopersicon esculentum* Mill.). Int. J. Agric. Res., 4: 46-52.

Jaoude, M.B., N. Katerji, M. Mastrorilli and G. Rana, 2008. Analysis of the ozone effect on soybean in the Mediterranean region: II. The consequences on growth, yield and water use efficiency. Eur. J. Agron., 28: 519-525.

Lestariningsih, I.D., Widianto and K. Hairiah, 2013. Assessing soil compaction with two different methods of soil bulk density measurement in oil palm plantation soil. Proc. Environ. Sci., 17: 172-178.

Li, D.M., J. Zhang, W.J. Sun, Q. Li, A.H. Dai and J.G. Bai, 2011. 5-Aminolevulinic acid pretreatment mitigates drought stress of cucumber leaves through altering antioxidant enzyme activity. Sci. Hortic., 130: 820-828.

Li, J.M., Z.R. Zou and X.Y. Wang, 2000. The present studying situation and existing problems of water-saving irrigation index for vegetable. J. Agric. Res. Arid Areas, 18: 118-123.

Li, W., X.L. Sui, L.H. Gao, H.Z. Ren and Z.X. Zhang, 2009. Effect of rapid dehydration on photosynthetic and fluorescent properties of cucumber leaves detached from low light treated seedlings. Eur. J. Hortic. Sci., 74: 210-217.

Ohashi-Kaneko, K., M. Yoshii, T. Isobe, J.S. Park, K. Kurata and K. Fujiwara, 2009. Nutrient solution prepared with ozonated water does not damage early growth of hydroponically grown tomatoes. Ozone: Sci. Eng., 31: 21-27.

Panahyan-e-Kivi, M., A. Ebadi, A. Tobeh and Sh. Jamaati-e-Somarin, 2009. Evaluation of yield and yield components of lentil genotypes under drought stress. Res. J. Environ. Sci., 3: 456-460.

Pinheiro, C. and M.M. Chaves, 2011. Photosynthesis and drought: Can we make metabolic connections from available data? J. Exp. Bot., 62: 869-882.

Posch, S. and L.T. Bennett, 2009. Photosynthesis, photochemistry and antioxidative defence in response to two drought severities and with re watering in *Allocasuarina luehmannii*. Plant Biol., 11: 83-93.

Subramanian, K.S., P. Santhanakrishnan and P. Balasubramanian, 2006. Responses of field grown tomato plants to arbuscular mycorrhizal fungal colonization under varying intensities of drought stress. Scientia Horticulturae, 107: 245-253.

USDA., 1992. National Soils Handbook. United States Department of Agriculture, Soil Conservation Service, Soil Survey Staff, Washington, DC., USA.

Wagner, T., 1993. Chamomile production in Slovenia. Acta Hortic., 344: 476-478.

Wang, Y.H., Y.F. Lin, J. Li and L.C. Lin, 2006. Effect of ozone and potassium sorbate in storage of Indian jujube fruit. Food Sci. Technol., 31: 258-260.

Zheng, Y., L. Wang and M. Dixon, 2007. An upper limit for elevated root zone dissolved oxygen concentration for tomato. Sci. Horticult., 113: 162-165.