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MORPHOLOGICAL CHARACTERISTICS OF TOMATO IRRIGATED WITH WASTEWATERS WITH DIFFERENT OXYGEN CONCENTRATIONS

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Abstract
Water scarcity is an ever-aggravating problem worldwide. In particular, there is greater emphasis placed on arid and semi-arid regions like Turkey. Although quite much progress have been achieved, several countries today are still faced to imbalanced water demands and water supplies especially in summer periods due to simultaneous low precipitations, high evaporations and increasing demands for irrigation. Major portion of irrigated agriculture is supported by fresh irrigation water resources, which are surface and groundwater. Not surprisingly, the decrease in natural water resources caused by drought and population growth enforced authorities to establish and to encourage the reuse of wastewater. In this study, different hygiene treatments (control, activated carbon treatment, activated carbon+hydrogen peroxide treatment, ozone treatment and hydrogen peroxide treatment) were used for the effluent of Ankara Municipal Wastewater Treatment Plant. Following hygiene treatments, wastewater was used as irrigation water for tomato. The oxygen concentration was achieved as 10 mg/l in all treatments. Oxygen treated wastewater had significant positive influences on some morphological characteristics of tomato.

Keywords: waste water, irrigation, oxygen, tomato

1. INTRODUCTION

Water scarcity is experienced worldwide especially in arid and semi-arid regions. Ever-increasing population and industrialization increase the demands for available fresh water resources. Since agriculture is the greatest water-user sector, savings should be initiated in agriculture to meet ever-increasing domestic and industrial demands. Decreasing water use in agriculture will bring a decrease in yield levels. Such a case will then aggravate the hunger already experienced worldwide. According to current data, increasing agricultural productions and decreasing hungers will only be possible through improving yields per unit area. Irrigation is the most significant input in improvement of yield levels and product diversity. It is possible to re-use effluent waters of all production processes based on their pollution levels through some treatment processes. Re-use of

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wastewaters may prevent the decreases in agricultural productions. Wastewaters are commonly used and will continue to be used as irrigation water in various parts of the world. Scott et al., (2004) indicated that more than 20 million hectare land area in 50 countries was irrigated with either raw or partially treated wastewaters.

The major objectives of wastewater irrigation are to provide a reliable source of water supply to farmers and to have beneficial aspects of adding valuable plant nutrients and organic matter to soil (Horswell et al., 2003; Liu et al., 2005). With careful planning and management, the positive aspects of wastewater irrigation can be achieved (WHO 2006). Treatment of wastewater, as a segment of water management, usually produces a liquid effluent of suitable quality that can be used for irrigation purposes with minimum impacts on human health or the environment (Blumenthal et al., 2000; Hussain et al., 2001; Qishlaqi et al., 2008).

Wastewater may be used directly or after mixing with sewage channeled into natural drainage systems, from where the polluted water is used for farming (Qadir et al. 2010). Most commonly, a year-round vegetable production is practiced, for which farmers have a good market. In many places in the world, this form of production has great importance as a source of income and livelihood for many people. Huibers and Raschid-Sally (2005) observed that farmers usually have no land rights and make use of available urban land belonging to property owners or the state, until they are thrown out.

In agriculture, irrigation water quality is believed to have an effect on the soil, the crop and the management of water (Shainberg and Oster, 1978). In particular, the use of untreated wastewater may result in a reduction of crop yield and deterioration in crop quality, while sodic water may adversely affect the physical properties of the soil with a consequent reduction in the yield. Considerable attention is presently being given to various aspects of water application, including the possibility of dispersing or creating even minute quantities of potentially harmful agents in the environment (Wang et.al., 2007).

Oxygation is the process of aerating irrigation water and employing SDI to deliver it to the root zone. Hyper-aerating irrigation water to increase the oxygen concentration is accomplished by either mixing air or by mixing peroxides such as hydrogen peroxide (H2O2) with irrigation water before it is distributed through the irrigation lines. Oxygation offers plant roots and soil biota extract oxygen with water during, or prior to, finishing each irrigation cycle, when soil air has been replaced by irrigation water (Shahien et al., 2014).

In this study, different hygiene treatments (control, activated carbon treatment, activated carbon+hydrogen peroxide treatment, ozone treatment and hydrogen peroxide treatment) were used for the effluent of Ankara Municipal Wastewater Treatment Plant. Then, the treated wastewater was used in tomato irrigation and the effects of treated wastewater on plant physiological characteristics were investigated.

2. MATERIALS AND METHODS

Experiments were conducted in greenhouses of Agricultural Structures and Irrigation Department of Ankara University Agricultural Faculty. Physical and chemical characteristics of soil used in experiments are provided in Table 1. Soils were placed into 40-liter pots and tomato seedlings were transplanted into these pots. Effluent water of Ankara Municipal Wastewater Treatment Plant was used as irrigation water and water quality parameters are provided in Table 2. Effluent waters were stored in 250-lite tanks and subjected to five different hygiene treatments (control, activated carbon, activated carbon+hydrogen peroxide, ozone and hydrogen peroxide).

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Irrigations were performed in frequent intervals as not to create a water stress on plants. Excess water was drained from the pot under free drainage conditions. The data on plant morphological characteristics were statistically analyzed through Jump statistical software.

Table 1. Soil characteristics

Parameter	Unit	Value	Parameter	Unit	Value
EC	(µs/cm)	436.5	Ca	ppm	2566
pH		7.98	Mg	ppm	137.19
OM	%	5.3	Cu	ppm	1.09
Texture	%	Clay loam	Fe	ppm	6.36
Lime	%	5.73	Zn	ppm	0.72
N	%	0.092	Mn	ppm	7.46
P	%	19.28	B	ppm	3.487
K	%	0.047			

Table 2. Irrigation water characteristics (Anonymous, 2007)*

PHYSICAL / PHYSICO-CHEMICAL PARAMETERS			
PH	7.66	Color (Pt-Co Unit)	35
Turbidity (NTU Unit)	5	Suspended Solids -SS (105 ^{o}C.mg/L)	9
Conductivity (20°C, µS/cm)	1176	Total Dissolved Solids- TDS (180^{o}C, mg/L)	823
CHEMICAL PARAMETERS			
Parameters	Unit (mg/L)	Parameters	Unit (mg/L)
Sodium	76.00	Carbonate (CO_3^{-2})	N.M.
Potassium	14.00	Bicarbonate ($HCO_3^{\ -}$)	417.00
Calcium	58.88	Chloride (Cl^-)	107.55
Magnesium	22.89	Sulphate (SO4-2)	104.70
Total Hardness (°FS)	24.14	Nitrate (NO_3^-)	9.70
Total Alkalinity (CaCO3)	342.00	Florid (F^-)	0.10
POLLUTION PARAMETERS			
Parameters	Unit (mg/L)	Parameters	Unit (mg/L)
Ammonia -Nitrogen	36.84	Oxidation rate (mg/IO_2)	20.00
Nitrite -Nitrogen	0.06	COD	74.00
Organic Nitrogen	2.47	BOD	30.00
Kjeldahl Nitrogen	39.31	Detergents (MBAS)	0.18
Total Nitrogen	41.56	Sulfide	0.56
Total Phosphate Phosphorus	4.30	Boron	1.00
Oil and Grease	N.M.	Total Cyanide	0.02
METALLIC AND OTHER PARAMETERS			
Parameter	Unit (mg/L)	Parameter	Unit (mg/L)
Iron (Fe)	0.23	Manganese	0.06
Aluminum	0.19	Copper	N.M.
Arsenic	N.M.	Lead	N.M.
Mercury (Hg)	N.M.	Cadmium	N.M.
Antimony	N.M.	Nickel	0.01
Selenium	N.M.	Cobalt	N.M.
Chromium (Cr *6)	N.M.	Zinc	0.10
Total Chromium	0.03	Tin	N.M.

3. RESULTS AND DISCUSSIONS

3.1 Plant Height

Waste water treatment plant effluents were subjected to different hygene treatments (control, activated carbon treatment (AC), activated carbon+hydrogen peroxide treatment (AC+O_2), ozone

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treatment (O_3) and hydrogen peroxide treatment (H_2O_2)) and applied to plant root regions as irrigation water. Plant heights were measured 6 times throughout 114-day growth season. Plant heights were subjected to statistical analyses and results are provided in Table 3. The differences in plant heights of the treatments were not found to be significant. The change in plant heights measured in each treatment is presented in Figure 1. Plant heights were higher in hydrogen peroxide treatments than the other treatments. It was followed by ozone and activated carbon + hydrogen peroxide treatments. In general, hydrogen peroxide treatments had positive effects on plant heights. The reason for such positive effects was oxygen enrichment of wastewater with hydrogen peroxide treatments. The oxygen in structure of hydrogen peroxide might have increased the oxygen content of wastewater. A similar effect was partially observed in ozone treatments. When the fully grown plants were considered in general, plant heights of activated carbon treatments were shorter than the plant heights of control treatment since activated carbon treatments held dissolved calcium and consequently reduced the oxygen content of wastewater. As it was known, activated carbon hold dissolved ions besides suspended solid.

Table 3. Statistical analysis results on plant morphological characteristics

Treatment	Height	Canopy	Diameter
Control	91.00	78.33 bc	1.17
Activated Carbon	86.67	71.67 c	0.99
Activated Carbon+O_2	100.00	77.33 bc	1.09
O_2	103.67	89.00 a	1.25
Ozone	89.67	80.67 b	1.27

Note: Means with the same letter are not significantly different

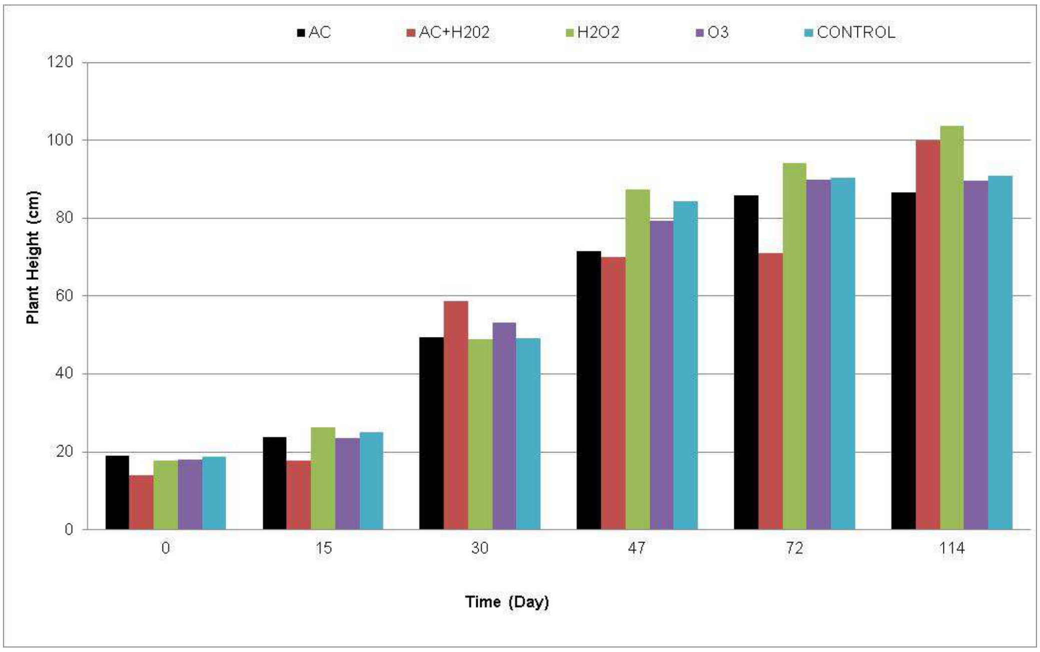

Figure 1. Change in plant heights

3.2 Plant Canopy Width

Effects of treatments on plant canopy widths were similar to effects on plant heights. Plant canopy widths were also subjected to statistical analysis and results are provided in Table 3. Effects of treatments on plant canopy widths were found to be significant ($p<0.01$) and LSD groups were presented in Table 3.

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The difference in plant canopy widths was quite remarkable in hydrogen peroxide treatments. Considering the ripening period, it was followed by ozone treatment and activated carbon + hydrogen peroxide treatments. In general, as it was in plant heights, increased oxygen concentration of wastewater had positive effects on plant canopy widths. Activated carbon holds calcium in wastewater and reduces oxygen concentration. In other words, it had negative effects on plant development.

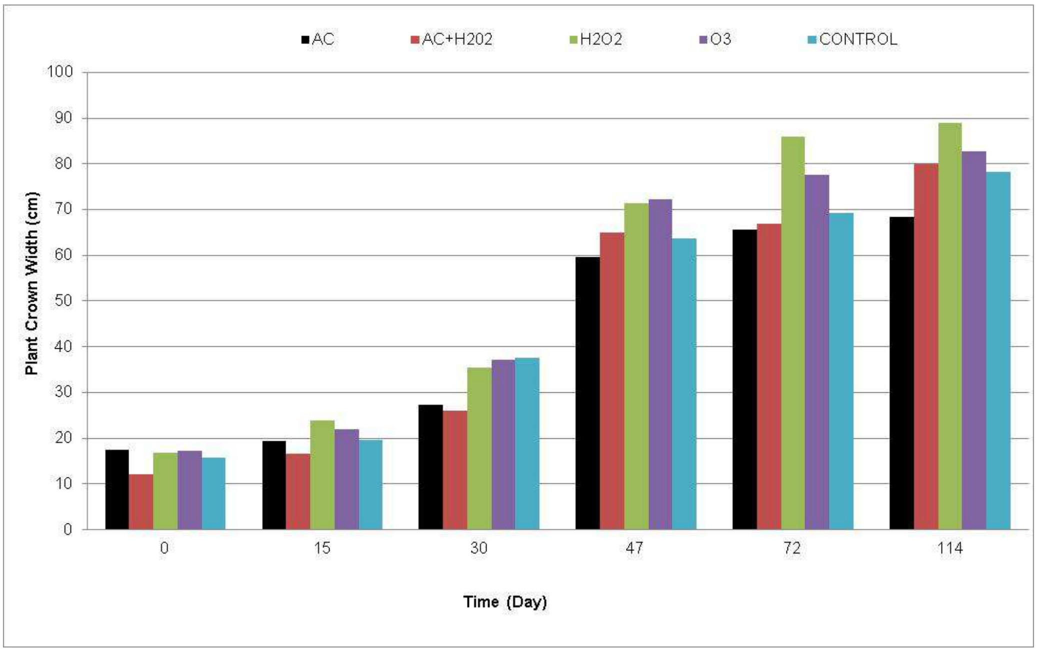

Figure 2. Change in plant canopy widths

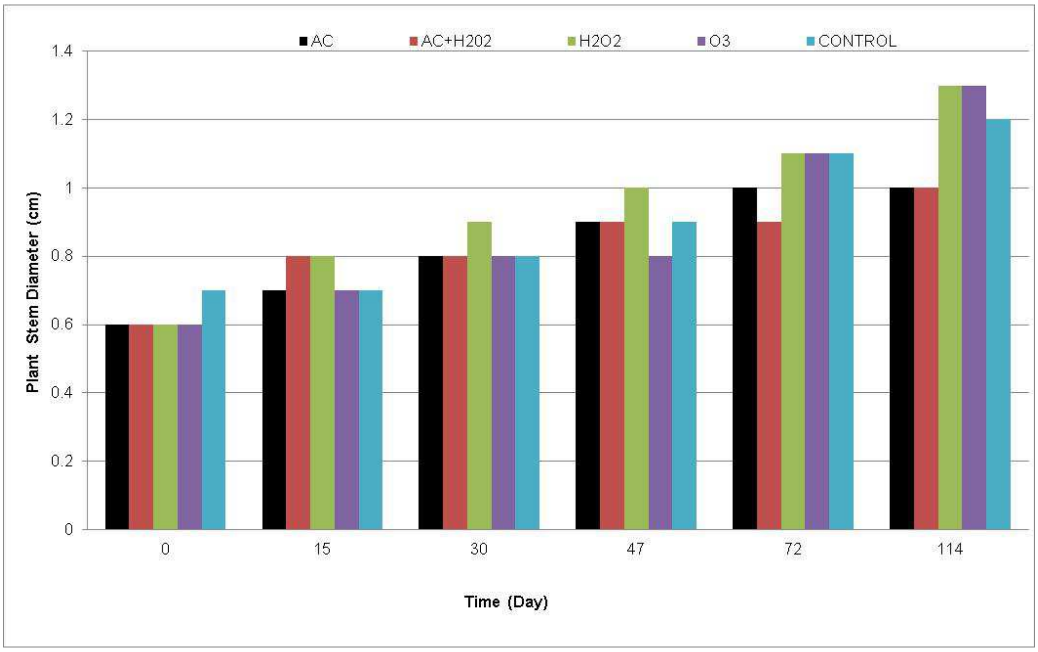

Figure 3. Change in plant stem diameters

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3.3 Plant Stem Diameter

Stem plays a significant role in both plant development and fruit formation. Considering the entire plant growth season, as it was in plant height and canopy widths, hydrogen peroxide treatments generally had positive effects on plant stem diameters. Stem diameters were subjected to statistical analysis and results are provided in Table 3. Effects of treatments on plant stem diameter were not found to be significant. Ozone treatments yielded similar effects with hydrogen peroxide treatments toward to ripening period. Increasing oxygen concentration of wastewater thickened stem diameters and yielded stronger stems.

4. CONCLUSIONS

Positive contributions of increased oxygen concentrations to both plant roots and soil microorganisms were reported by previous researchers (Huber, 2000; Goorahoo et al., 2002; Bhattarai et al., 2004 and Shahien et. al., 2014). Oxygen concentration is even more significant when the wastewaters are used for irrigation. As it was well-known that wastewaters have low oxygen concentrations. In other words, both biological and chemical oxygen demands are tried to be met during the entire processes of wastewater treatment. Oxygen enrichment of wastewaters to be used as irrigation water can provide significant contributions to plant growth. Hydrogen peroxide treatments may significantly improve oxygen concentrations of wastewaters. Such treatments may also prevent biofilm formation and dripper clogging especially in surface and sub-surface drip irrigation implementations.

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