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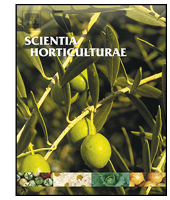

Effect of using raw waste water from food industry on soil fertility, cucumber and tomato growth, yield and fruit quality

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ABSTRACT

Raw waste water (RWW) from food industry is rich of organic matter and mineral nutrients, particularly, K and to lesser extents N then P. Such richness is attributed to the nature of some substrates involved in the food processing e.g. molace of sugar beet or sugar cane. These two crops are known to require high amount of K and, thus, to further enrichment of their derivatives with that nutrient. As cost of K fertilizers is relatively high, this experiment was conducted to study the effect of applying RWW on soil fertility, yield quantity and quality of greenhouse cucumber and tomato. Uniform 30-day old cucumber seedlings and 45-day old tomato seedlings were transplanted to two multi-span greenhouses (1000 m^2) on December 12, 2012, at Dair Alla Research Station in Central Jordan Valley (JV). The transplanted seedlings were subjected to 5 RWW treatments of 75% of the traditional amount of K fertilizer farmers of the JV apply during the growing season, 100% of K of the traditional amount of K-fertilizer of which 25% were applied before transplanting and 75% were applied during the growing season, 125% of the traditional amount of K-fertilizer where 25% were added to the soil before transplanting and 100% were added during the growing season, traditional amounts of N, P and K chemical fertilizers, and traditional amounts of N and P chemical fertilizers only. The results showed that RWW can effectively substitute K-chemical fertilizer and can also improve some soil fertility parameters by the end of the growing season. For example, increases in available K and organic matter in the RWW treated cucumber beds were 25–71% and 2–11%, respectively. Similar increases were reported in the case of tomato beds (7–62% and 7–17%). Such increases corresponded to increases in K uptake by cucumber and tomato plants (30 and 37%, respectively). Calcium uptake was also increased to levels as high as 40 and 34% in both crop cases. Results of this study indicated that the application of Raw Waste Water from Food Industry improve cucumber and tomato performance and soil fertility.

1. Introduction

Jordan is one of the most water scarce countries in the world (probably the poorest) with approximately 145 m^3 of available water resources per capita per year. This number is below the widely recognized “water poverty line” of 1000 m^3 per capita per year (Water Strategy of Jordan, 2008–2022Water Strategy of Jordan, 2008–2022). This critical situation is further aggravated by the new influx of more than 1.5×10^6 Syrian refugees in the repercussion of the Syrian civil war. These refugees added extra burden on the already exhausted water resources. In such a situation the country has to optimize management of its limited water resources (Abu-Sharar and Battikhi, 2002). Oster (1994) acknowledge the necessity of using poor quality waters in irrigation as the industrial and municipal needs grow in a pace higher than the growing World population. Because of the growing shortage in fresh water supply for irrigation, the Jordan’s Standard Specifications of Reclaimed Industrial Waste Water (JS 202/2007) allows, in certain cases, the reuse of waters of such properties in irrigation. However, the legislator required early field study aimed at the demonstration of

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sound environmental and public health safety in such cases (Article 4–5 of the former Standard). Raw waste water (RWW) of the food industry is particularly rich in K (~4 g/l) (Table 3). This water also contains organic matter and variable levels of macro- and micronutrients (Table 3). In this regard, Abu-Sharar (2002) reported the safe application of the RWW of that quality in irrigation of alfalfa field. The author concluded that the RWW of that industry can alternatively be utilized in conjunction with fresh water to produce alfalfa. The author also indicated maximum water use efficiency by alfalfa when the alternative irrigation comprised one portion of RWW to be followed by three portions of fresh water. Similar studies on the use of reclaimed industrial wastewater (Prazeres et al., 2014) and domestic wastewater (Aiello et al., 2007; El-Hamouri et al., 1996) were carried out to investigate the impacts of these waters on tomato yield and quality and on soil and environment. Since the earlier studies didn't take into account the optimization of K-use efficiency by irrigated crops, taking into consideration both water shortage and cost of K-chemical fertilizer in one irrigation practice would be of paramount importance. According to Agricultural Bulletin (Department of Statistics, 2011), the costs of KNO_3 and K_2SO_4 fertilizers were about 1.0 US$ per kg of either fertilizer or 2.5 and 2.3 US$ per kg of elemental K, respectively. These prices were much higher than that of unit N-fertilizer. For example, the price of one kg of urea-N at the same period was 1.1 US$ per kg urea-N. Subsequently, this work was initiated to study the possibility of substituting K-chemical fertilizer by RWW-K. The effect of RWW-K on fruit yield of cucumber and tomato growing in green house in the Central Jordan Valley (JV) was evaluated. Irrigated soil characteristics and other crop indicators like plant vegetative growth and selected plant mineral nutrient contents were also examined.

2. Materials and methods

2.1. Crop cultivars

Two crop cultivars of greenhouse vegetables were used in these experiments; cucumber (*Cucumis sativus* L.) "RS 24189 F1" from Royal Sluis Com. (USA), and indeterminate tomato; (*Solanum lycopersicum* Mill.) "Newton" from Syngenta Company, The Netherlands. The cultivars were selected as they are the ones of the most commonly growing under protected environment in the JV.

2.2. RWW treatments

Uniform 30-day old cucumber seedlings and 45-day old tomato seedlings were transplanted into two multi-span greenhouses (1000 m^2 area) on December 12, 2012, at Dair Alla Research Center in Central JV. The seedlings were transplanted in raised beds after addition of farm manure (40 tons per ha) in November, 2012. The multi-span greenhouses were equipped with drip irrigation network and polyethylene black mulch. The fertilizer treatments are summarized in Table 1. With the exception of the treatments, the crops enjoyed similar agricultural management including the traditional application of all other macro- and micro- nutrients as shown in Table 2. Each treatment comprised five 6 m long rows of raised beds, 30 plants each. The experimental design was randomized complete block design (RCBD) with three replicates for each crop. The subsequent statistical analysis was carried out according to Cochran and Cox (1957). Analysis of variance (ANOVA) was conducted to determine significant differences and mean separation at 0.05 level using Duncan multiple range test.

Surface soil was sampled for appropriate analyses before the commencement and at the end of the field experiment. Five plastic tanks, each 2 m^3 capacity, were placed in adjacent area to supply the treatments with their respective needs of the RWW and other appropriate chemical fertilizers of $(NH_4)_2SO_4$, $Mg(NO_3)_2$, $Ca(NO_3)_2$ and KNO_3 (El-Zuraiqi et al., 2004). Foliage application of P, as orthophospheric acid and mineral salts of micronutrients was practiced from separate solutions adjusted at pH 6.5–7.0 to maintain most of P as $(H_2PO^-{}_4)$. Crop water requirement was based on Class A pan readings 15 and 25 days following cucumber and tomato transplanting, respectively. The Pan was placed in the multi-span plastic house and the obtained readings were multiplied by the respective crop coefficient (Allen et al., 1998). Volumes of good quality irrigation water were 4750 m^3 ha^{-1} for tomato and 3570 m^3 ha^{-1} for cucumber. These volumes were applied during growing periods of January 15, 2013 through April 15, 2013 for cucumber and January 15, 2013 through May 30, 2013 for tomato, respectively. A 2 m^3 of irrigation water were delivered to each crop treatment in the early period of 15 or 25 days. Chemical analyses of irrigation water were carried out on a monthly basis following standard methods of analysis (Ryan et al., 2001). Sodium, K, Mg and Ca concentrations were determined using Varian Spectra AA 200 Atomic Absorption Spectrophotometer. Irrigation with treatmental RWW was initiated on the 15th of January, 2013.

Table 1
Summary of the fertilizer treatments.

Treatment 1	75% of traditional K fertilizer from the RWW
Treatment 2	100% of traditional K fertilizer from the RWW divided into two portions: 25% before transplanting and 75 % added during plant growth
Treatment 3	125% of traditional K fertilizer from the RWW divided into two portions: 25% added to the soil before transplanting and 100 % added during plants growth
Treatment 4	Traditional farmers' method of chemical N, P and K fertilizers application
Treatment 5	Traditional farmers' method of chemical N and P fertilizers application with zero K fertilizer

Note: Traditional amounts of K-fertilizer application to cucumber and tomato fields are 45 and 65 kg K ha^{-1}, respectively (El Zuraiqi et al., 2004).

2.3. Crop performance indicators

2.3.1. Plant height, plant fresh and dry weight and leaf area

Plant height was measured for ten plants in each treatmental replicate selected randomly on 90th after seedling transplanting. Plant dry weights were measured on the 120th day after seedlings transplanting. Three plants from each treatment replicate were selected randomly for this purpose. The aerial and root parts of each plant were carefully removed, washed with distilled water, placed on filter paper and air dried to evaporate the wetting water at room temperature (22–25 °C). Separate fresh plant parts of roots, stems and leaves were then employed in the determination of fresh mass and the measurement of leaf area. Afterword, these parts were dried at 60 °C and constant mass was reported (AOAC, 1990). Dry weights were determined using laboratory ventilated oven (1445 SHEL LAB). Leaf area was determined using Portable Area Meter (LI-3000 A). The dry plant material was used for nutrient analysis.

2.3.2. Mineral composition

Oven dry plant shoot and fruit samples, from both crops, were used for mineral analysis according to (AOAC, 1990). In brief, the samples were dried to 60 °C using ventilated oven (1445 SHEL LAB) then the samples were ground using stainless steel blender. Samples from the ground materials were ashed at 450–500 °C for 4 hrs using Thermo Scientific Muffle Furnaces (Thermolyne®). A 10 ml of 0.1N HNO_3 were added to 100 mg of the plant ash then the mixture was heated for 10 min. The resulting solution was then filtered into 50 ml volumetric flask. An additional 10 ml of the HNO_3 solution was added to the residue of plant ash for further dissolution of that material and finally the volume of the filtrate was made to 50 ml