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Impact of Intensive Greenhouse Production System on Soil Quality

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ABSTRACT

Composite top- and subsoil samples were collected from the greenhouses in the Al-Balawneh area, Jordan, where intensive greenhouse production system (IGPS) has been practiced since 1998, to study the impact of IGPS on soil quality as measured by the chemical and biological properties to develop a sustainable production system. The study showed that IGPS led to higher electrical conductivity in top- and subsoils compared to an uncultivated soil (control). Quality and amount of irrigation water, lack of efficient drainage, and quantity and types of applied fertilizers were major factors resulting in salt buildup. IGPS resulted in lower total N (TN) and NO_3-N in the soil compared to the control. The lower TN was due to crop uptake, microbial immobilization, volatilization, and irregular application of composted animal manure or poultry manure. In contrast, higher residual Olsen-P content was detected in both soil layers of greenhouses than in the control. Residual P was classified as very high in the topsoil layers and sufficient to high in the subsoil layers. Residual available K in the soils of greenhouses was relatively lower than that in the control and it was, however, classified as high to very high. A large increase of Cl and a considerable decrease in the bacterial count were observed in both soil layers of IGPS compared to the control treatment. Economically sustainable soil management practices need to be adopted by farmers to achieve a sustainable and profitable production. This can be accomplished through education, targeted towards the farming community in the central Jordan Valley.

Key Words: central Jordan Valley, salt buildup, soil health, soil management, unsustainable agriculture practices

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INTRODUCTION

The unsustainable agricultural practices during the last few decades are the main causes for environmental degradation in the West Asia and North Africa regions, including Jordan, especially through their impacts on soil and water resources. Consequently, there is an increasing interest in sustainable and environmental friendly intensive greenhouse production systems that optimize yields while sustain soil, fauna, water and energy, and protect the environment. Jordan Valley is the most potential agriculture area in Jordan, where a variety of long-term intensive greenhouse agricultural activities (*i.e.*, irrigation, fertilization, *etc.*) are undertaken. The area supplies food and cash crops such as vegetables (tomato, pepper and others), fruits, and bananas. Up to now, the sustainability of such activities is not yet assessed. To enforce sustainable agricultural development and to collect essential environmental information, a regional chemical and biological survey of soils should be conducted in the Jordan Valley. Data from such regional survey can play an important role in evaluating the impact of long-term intensive greenhouse production practices on soil quality, *i.e.*, soil fertility and soil chemical and biological properties. The major objective of soil quality/fertility assessment is to predict, from the knowledge of soil properties, the ability of the soil to support specific functions for the crop, animals-humans, and water target systems (Harris and Bezdicek, 1994). It could be also used as a management tool to help farmers to select specific management practices (*e.g.*, fertilization) and as a measure of sustainability (Doran and Parkin, 1994). Most recently, Hu *et al.* (2012) reported that an investigation of the actual status of soil fertility in the intensive greenhouses could enable stakeholders to develop fu-

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ture strategies for nutrient management and sustainable agriculture through saving inputs and preventing environmental damages resulting from nutrient losses.

Local field observations suggest that many production systems are fertilized in excess; *i.e.*, fertilizers are applied in excess of plant demands for optimum yield, without any criteria that allows for a rational use of mineral as well as organic fertilizers. In fact, diagnostic tools of soil nutrients and nutritional status of growing crops are often disregarded, since few growers perform soil and/or leaf analysis on a regular basis. This might be due to farmers' perception that an increase in fertilization always results in a yield increase. However, an excess of, for example, N may cause environmental degradation (Giménez *et al.*, 2001). According to Weinbaum *et al.* (1992), over-fertilization seems to be a common practice because of the failure to consider non-fertilizer sources of plant available N and conduct annual diagnosis of the N status in addition to the insensitivity of leaf N to over-fertilization. Indeed, nutrients added by irrigation water, released from organic matter and/or crop residues mixed with soils, and residual amounts of nutrients (from previous seasons) are neither quantified nor considered by many growers including those of the Jordan Valley. Therefore, to ensure adequate returns on agricultural investment (*i.e.*, reducing the per-unit production costs), cost-effective utilization of fertilizers should be accomplished.

The impacts of intensive greenhouse agricultural activities on the quality of the soil and water resources of a region should be studied in combination with the characteristics and particularities of the area in which these activities take place. Especially in the Jordan Valley region, the soil quality/fertility assessment is a difficult task. The area is characterized by high soil and climate diversity which results in a large number of management practices in a constricted area. Accordingly, this study was conducted in 2012 in Al-Balawneh area of the central Jordan Valley where intensive agricultural activities were practiced since 1998. To our knowledge, the long-term impact of intensive greenhouse production practices on soil chemical and biological properties in the central Jordan Valley has not been assessed yet. Thus, the main objectives of this study were: i) to determine the residual nutrient pool in soils and soil chemical and biological properties under the conditions of intensive tomato and pepper greenhouse production systems, ii) to investigate the impact of intensive greenhouse production system (IGPS) on soil quality/fertility, and iii) to suggest sustainable and environmental friendly greenhouse management practices. Such information could play a future strategic role in soil nutrient management planning decisions.

MATERIALS AND METHODS

Study area

The Jordan Valley, the main agricultural region in Jordan, is characterized by an arid Mediterranean, very warm bioclimate. This area has a mean maximum temperature varying between 22 and 40 °C during summer months due to different altitudes (Al-Zu'bi and Al-Kharabsheh, 2003). The month of July is the hottest and January is the coldest during which the mean temperature drops to a minimum of 7 °C. The mean annual precipitation ranges between 250 and 300 mm, which is typical for arid regions. The maximum reference evapotranspiration is 205.7 mm during July, while the minimum is 72.4 mm during January. Water consumption in the valley ranges from 2 000 to 8 000 m^3 ha^{-1} $season^{-1}$.

Reclaimed wastewater from the As-Samra Wastewater Treatment Plant was supplied to the central part of the Jordan Valley. On its course to the Jordan Valley it was diluted by surface runoff water from adjacent catchment areas and temporarily stored in the King Talal Reservoir. Although diluted, this reclaimed water contained nutrients and some salts, heavy metals and microbial contaminants. This irrigation water was classified as Class B water with a salinity range of 0.45–2.00 g L^{-1} (FAO, 1993).

The pH values, $CaCO_3$ content, and organic matter content of the soils in the Jordan Valley ranged from 7.1 to 8.7, 100 to 650 g kg^{-1}, and 3 to 48 g kg^{-1}, respectively, in the topsoil (0–20 cm) and from 7.3 to 8.5, 50 to 700 g kg^{-1}, and 3 to 35 g kg^{-1}, respectively, in the subsoil (20–40 cm). Composted animal manure (mixtures of different ratios of poultry, sheep and cow manures) was applied annually and mixed with the upper 20 cm soil layer before growing crops in the Jordan Valley, particularly in greenhouses, with the amount of 10 to 20 t ha^{-1} $year^{-1}$ (Ammari *et al.*, 2013).

Agricultural practices

Soil samples were collected from the Al-Balawneh area (central Jordan Valley). The agricultural practices at the study site represented typical management of crops and soils under greenhouse conditions in the central Jordan Valley. Intensive greenhouse production system has been practiced at the study site since 1998, where greenhouses (500 m^2 each) were cultivated with tomato and pepper crops. Crops were irrigated with the water from King Abdullah Canal till 2009 and alte-