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Evaluation of humic substances fertigation through surface and subsurface drip irrigation systems on potato grown under Egyptian sandy soil conditions

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ABSTRACT

The aim of this study was to evaluate the effect of humic substances application in sandy soil under surface and subsurface drip irrigation systems on potato tubers yield quantity, quality, nutrients concentration in tubers and soil fertility after harvesting. For this purpose, field experiment was carried out at the experimental farm of the Agricultural Research Station, National Research Center, El-Nubaria district, Egypt during the winter season of 2007/2008. The used experimental design was split plot design with three replicates, main treatments were presented irrigation systems, i.e. surface and subsurface drip irrigation, while subtreatments were presented rates of humic substances additives which were 0, 60 and 120 kg ha^{-1}. Results showed that increasing humic substances application rates up to 120 kg ha^{-1} enhanced tubers yield quantity, starch content and total soluble solids. The increase of humic substances application rates was associated with the decrease of nutrients leaching, which was reflected on increasing macro- and micronutrients concentration in potato tubers, as well as increasing concentration of these nutrients in soil after tubers harvesting. Subsurface drip irrigation system was found to be more efficient than surface drip irrigation system on improving tubers yield quantity, quality parameters and nutrients concentration content, in addition to soil fertility after harvesting.

1. Introduction

During the past century, Egyptian population has increased more than five times, from 11 million in 1907 to more than 70 million at the beginning of the year 2007, while the area of its cultivated land has changed slightly from 2.3 million hectares to approximately 3.6 million hectares during the same period, and this has led to a shortage in food supplies. Consequently, management of sandy soils through proper reclamation measures to increase crop productivity assumes a great deal of interest in a day wherein the available land area for cultivation is declining all the time.

There are specific problems in the management of sandy soils including their excessive permeability, low water and nutrient holding capacities (Suganya and Sivasamy, 2006). Therefore, managing the use of irrigation water and plant nutrients is a major challenge of sandy soil amelioration efforts.

The term 'micro-irrigation' refers to drip, trickle, spray, micro-jets or mini-sprinkler systems designed to use available water more effectively that slowly and frequently provides water directly to the plant root zone. Moreover, drip irrigation provides an efficient method of fertilizer delivery virtually free of cultural constraints that characterize other production systems. Subsurface drip irrigation is considered to be the most modern irrigation system with efficient water delivery that can contribute immensely on improving crop water use efficiency and conserving water (Hanson and May, 2004). Most agricultural irrigation scientists are in agreement that fertilization through subsurface drip irrigation system could be the ideal fertigation systems. Rajkumari et al. (2006) hypothesized that injecting N fertilizer into subsurface irrigation systems should in theory be as efficient as the irrigation delivery system itself is.

Achieving maximum fertigation efficiency requires knowledge of crop nutrient requirements, soil nutrient supply, fertilizer injection technology, irrigation scheduling, crop and soil monitoring techniques. If properly managed, fertigation through drip irrigation lines can reduce overall fertilizer application rates and minimize adverse environmental impact of vegetable production (Hochmuth, 1992).

Humic substances are the final component of organic matter decomposition, and its benefits in agricultural system are its ability to capture more moisture content, which will increase water use efficiency in the amended sandy soil when compared with the unamended one. This could be due to the phenomenon of swelling and retention of water by the amended soil (Suganya and Sivasamy, 2006). Otherwise, humic substances are able to complex metal ions

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Table 1
Averages of air temperature, relative humidity, pan evaporation and total precipitation during the growing season.

Month	Average temperature (°C)	Average relative humidity (%)	Average pan evaporation (mm)	Total precipitation (mm)	Average wind speed (km day^{-1})	Monthly evapotranspiration (m^3 $month^{-1}$)
November	22.7	59.0	3.7	6.0	108.71	555.0
December	18.1	58.0	2.0	22.0	118.5	465.0
January	14.9	61.3	2.7	36.0	122.26	627.8
February	13.9	61.0	2.4	17.0	129.25	522.0

(Stevenson, 1982) which will decrease nutrients leaching with irrigation water, and increase fertilizers use efficiency. Humic substances are relatively stable products of organic matter (Mackowiak et al., 2001); accumulate in the environmental systems to increase moisture retention and nutrient supply potentials of sandy soils (Suganya and Sivasamy, 2006).

Intense competition for reduced international supplies of cereals and other agricultural commodities is driving worldwide food price inflation, which brings with it the risk of food shortages and social unrest in low-income countries. One strategy that could help to reduce this risk is the diversification of food production to nutritious and versatile staple crops that are less susceptible to the vagaries of international markets, and the best one of such crops is potato.

Potato (*Solanum tuberosum* L.) is a major food crop in many countries, it rates the fourth ranking among the world's various agricultural products in production volume, and it comes after wheat, rice and corn (Fabeiro et al., 2001). Potato is relatively sensitive to water stress that yield reductions and loss in tuber grade, which makes the availability of soil water one of the most important factors affecting the yield and quality of potato (El-Ghamry and El-Shikha, 2004).

The main aim of our study is to examine the extent to which humic substances additives could be effective in improving potato tubers yield, tubers quality parameters and its nutrients concentration as well as nutrients remained in soil after harvesting stage under both surface and subsurface drip irrigation systems in sandy soil to be included in the fertigation systems.

2. Materials and methods

2.1. Location of the experiment and its layout

Field trial was conducted at the Agricultural Research Station, National Research Centre, El-Nubaria district, Egypt (latitude of 30°30N and longitude of 30°20E) during the winter season of 2007/2008, in a sandy soil (*Entisol-Typic Torripsamments*).

The used experimental design was split plot design with three replicates. Main plots were assigned to the two irrigation systems, i.e. surface and subsurface drip irrigation. Sub-plots were presented humic substances application levels, which were 0, 60 and 120 kg ha^{-1}. The area of each plot was 100 m^2; hence, the total area of the field experiment was 1800 m^2. Plants row spacing was 0.75 m, and the distance between each plant was 0.25 m.

2.2. Climatic conditions

The meteorological data were taken from Mansoura meteorological station according to the formal data from the Egyptian Ministry of Agriculture. Reference evapotranspiration was calculated by pan evaporation method, which obtained from the following equation:

$$ET_p = K_p E_{pan}$$

where K_p is the pan coefficient, depends on type of pan conditions, i.e. humidity, wind speed and pan environmental conditions (0.75). E_{pan} the pan evaporation in mm/day, and represents the mean daily value of the period considered.

Some meteorological data and evapotranspiration during the growing season are presented in Table 1.

2.3. Soil sampling and analysis

Surface soil samples (0–40 cm) were collected from the experimental field, the collected samples were air-dried, crushed, and passed through a 2-mm sieve and preserved for analysis. To judge soil characteristics perfectly the following ideal methods were used:

Particle size distribution for soil was carried out using the pipette method as described by Dewis and Fertias (1970). Field capacity of the soil was determined using the methods described by Richards (1954). Hydraulic conductivity was determined using Darcy equation by the method described by Singh (1980). Total carbonate was estimated gasometrically using Collins Calcimeter and calculated as calcium carbonate according to Dewis and Fertias (1970). Soil reaction (pH) was measured in saturated soil paste using combined electrode pH meter as mentioned by Richards (1954). Total soluble salts were determined by measuring the electrical conductivity in the extraction of saturated soil paste in dS m^{-1} as explained by Jackson (1967). Amounts of water soluble cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and anions (CO_3^{2-}, HCO_3^- and Cl^-) were determined in the extraction of saturated soil paste by the methods described by Hesse (1971), whereas (SO_4^{2-}) ions were calculated as the difference between total cations and anions. Soluble Ca^{2+} and Mg^{2+} were determined by titration with standardized versenate solution. Soluble Na^+ and K^+ ions were determined by using flame photometer. Soluble CO_3^{2-} and HCO_3^- ions were determined by titration with standardized H_2SO_4 solution. Soluble Cl^- ions were determined by titration with standardized silver nitrate solution.

Soil available nitrogen was extracted using KCl (2.0 M) and determined by using macro-Kjeldahl method according to Hesse (1971). Soil available phosphorus was extracted with $NaHCO_3$ (0.5 M) at pH 8.5 and determined colorimetrically after treating with ammonium molybdate and stannous chloride at a wavelength of 660 nm, according to Jackson (1967). Available potassium was determined by extracting soil with ammonium acetate (1.0 M) at pH 7.0 using flame photometer as described by Hesse (1971). Available iron, zinc and manganese were extracted using DTPA method (Lindsay and Norvell, 1978), and measured using atomic absorption spectrophotometer PerkinElmer model 5000.

Some physical and chemical properties of the experimented soil are listed in Table 2.

2.4. Irrigation setup

The drip irrigation lines were twin-wall drip tapes (GR is the common commercial name), with outlets spaced every 0.5 m, and the drippers used were of a standard 4 L/h discharge at 1.5 bar working pressure. Drip irrigation lines laid above and under ridges of plant rows, and the installation depth of the subsurface drip lines was 0.25 m. The spacing between lateral lines was 0.5 m, and