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EFFECTS OF MUNICIPAL SEWAGE IRRIGATION ON THE GROWTH OF TOMATO PLANTS ON SANDY SOILS AT KALPAKKAM, TAMIL NADU, INDIA

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ABSTRACT

Tomato saplings, irrigated with municipal raw sewage (RS) and treated sewage (TS), compared to that of potable water (PW) on sandy soils at Kalpakkam in Tamil nadu (India) showed significant increase in plant-height, number of branches, leaves and fruit yield in the plants irrigated with raw sewage during the crop season of three months. These growth parameters showed close relationship with the nutrient contents of municipal RS, TS and PW; the former being characterized by relatively higher pH, electrical conductivity (μS/cm), total dissolved solids, total suspended solids, total hardness, chloride, sulphate, BOD, COD, calcium, magnesium, sodium, potassium, bicarbonates, total alkalinity, nitrate, phosphate and carbonates compared to that of the TS and PW, which probably enhanced the growth traits.

INTRODUCTION

Municipal wastewater irrigation in agriculture and the land application of sewage sludge or biosolids are traditional practices across the world. Paris, for example, had sewage farming as early as 1863. The use of sewage for the irrigation of governmental farms in Egypt has been in implementation since 1915. Braatz & Kandiah (1996) reported that the practice of irrigating agricultural crops with municipal wastewater has become more widespread, especially in arid and semiarid areas of both developed and developing countries in the past two decades. A survey of current wastewater reuse practices in developing countries carried out by the United Nations Development Programme (UNDP) and World Bank (1991) estimated that some 80% of the wastewater from urban areas in developing countries is currently used for permanent or seasonal irrigation. Untreated wastewater is used to irrigate at least 500,000 hectares in Latin America with over half of this area in Mexico (Rodríguez et al. 1994, Moscosco 1996). Mexico City’s wastewater use scheme is the largest in the world and wastewater use is practiced throughout the country in most cities with a sewage system. The potential for using reclaimed secondarily treated effluent for the production of vegetable crops has long been recognized in other countries (Day et al. 1979). The controlled use of untreated and treated wastewater in irrigation is now quite common in Europe, United States, Mexico, Australia, China, India and the Near East as well as, to a lesser extent, in Chile, Peru, Argentina, Sudan and South Africa (Bartone & Arlosoroff 1987). China and India make significant reuse of wastewater (Bartone 1991). In China, for example, over 1.33 million ha, mainly croplands, are irrigated with wastewater. Strauss & Blumenthal (1990) estimated that 73,000 ha were irrigated with wastewater in India. Presently 6351 million cubic meter of wastewater is being generated every year in India from 212 class I and 242 class II towns in the country, of which only 36% in class I cities and 14% in class II towns are collected due to limited treatment facilities (Thawale 2006).

The discharge of treated wastewater, enriched with nutrients and with other pollutants, can cause eutrophication of lakes, reservoirs, rivers and streams, besides creating aesthetic problems. This warrants adoption of an appropriate wastewater management system where in twin benefits of treatment i.e., recycling as well as reuse can be achieved. The treated sewage effluents are mineral enriched and are considered an alternative supply of water and nutrients, when destined to crop irrigation (Bouwer & Idelovitch 1987). The nutrients in sewage like nitrogen, phosphates and potassium along with the micronutrients as well as organic matter could be added advantageously with sewage irrigation adding fertility to the soil, along with the irrigation potential of the water. Kaddous et al. (1986) calculated that the use of reclaimed water represented approximately a 35 % saving in fertilizer cost because reclaimed water saved about 60 %, 33 % and 40 % of inorganic nitrogen, phosphorus and potassium fertilizer respectively.

Most wastewater irrigation in India occurs along rivers, which flow through such rapidly growing cities like as Delhi, Kolkata, Coimbatore, Hyderabad, Indore, Kanpur, Patna, Vadodara and Varanasi. It has been reported that the Indian city of Hubli-Dharwad generates approximately 60 million litres of wastewater per day (Hunshal et al. 1997), which is discharged untreated through the open city drains (wastewater nallahs) into natural courses that flow into the hinterlands. Along the main wastewater nallahs three distinct cropping systems such as vegetable production, field crops with vegetables, and agroforestry are irrigated with waste (Bradford et al. 2002). Garg & Priya (2006) studied the influence of short-term irrigation of textile mill wastewater on the growth of chickpea cultivars in Hisar in India. The present study reports the effect of municipal raw sewage (RS) and treated sewage (TS) irrigation in comparison to that of potable unpolluted water (PW) on the growth and yield of tomato plants.

MATERIALS AND METHODS

Study Site

The present study was carried on sandy soils at Kalpakkam township (12º30” N and 80º10” E) located in Kancheepuram district of Tamil Nadu in the east coast of India. Experimental plots each of size 6 × 4 sq. ft were prepared with randomized block design with separate irrigation channels of municipal RS, TS and PW, and each treatment with six replicates. Six tomato saplings were planted in each of the replicate plots. Municipal RS and TS from the extended aeration activated sludge system of Kalpakkam and PW were channeled to these plots for irrigation during a crop season of three months from January to March 2006.

Physico-Chemical Analysis

The physico-chemical characteristics like pH, electrical conductivity (μS/cm), total alkalinity, total hardness, total dissolved solids, total suspended solids, BOD, COD, nitrate nitrogen, chloride, sulphate, phosphate, sodium, potassium, calcium, magnesium, bicarbonates and carbonates (mg/L) and field temperature of municipal RS, TS and that of PW were analysed following methodology described in APHA (1998).

Plant Growth Measurements

The height, number of branches and leaves of each tomato plant in each replicate plot across the treatments were recorded every month. The root length of each of the saplings was measured across the treatments at the end of the experiment. These plants were left without irrigation for fruit ripening during half of the fourth month. Numbers of tomatoes and their weight in each plot were recorded.

Statistical Analysis

The data on height, number of branches, leaves and fruit yield of the tomato plants grown in municipal RS, TS and PW during the crop season were analysed using ANOVA. Multiple correlation analysis was computed between the growth traits of tomato plants grown in RS, TS and PW in relation to the nutrient concentration of the sewage.

RESULTS AND DISCUSSION

Water-Quality Parameters

Analysis of water quality parameters of municipal RS, TS and PW used for irrigation of tomato saplings showed that their average concentration in municipal RS was higher than that of the TS, which was higher than that of the PW (Table 1). The average field temperature of the RS, TS and PW were 27.8, 27.2 and 27ºC respectively, the slight increase in temperature in RS was probably because of its relatively higher microbial activity. The average value of pH in municipal RS was 7.1, which slightly decreased to 6.8 in TS and further to 6.73 in PW, and that of electrical conductivity in municipal RS was 747 µS/cm, which decreased to 630 and 613 µS/cm in TS and PW respectively. The average values of the TSS and carbonate in municipal RS were 375.3 and 10.8 mg/L, which decreased to less than six and three times to 58 and 2.9 mg/L in the TS and to 14 and four times less to 4.0 and 0.62 mg/L in the PW respectively. Sulphates and potassium in RS were 64 and 58 mg/L, which decreased to 50 and 31 mg/L in TS and to less than two and three times to 22 and 10 mg/L in PW respectively. The average values of COD, BOD, total alkalinity, nitrates, phosphates and sodium in municipal RS were 436, 240.6, 234, 45.6, 1.2 and 166.3 mg/L, which decreased to less than two, nine, two, two, three and two times to 214, 24.3, 103, 18, 0.36 and 70.9 mg/L in the TS and to 133.4, 6, 101.4, 14.5, 0.21 and 41.2 mg/L in PW respectively. The average values of TDS, chloride, calcium and total hardness in municipal RS were 481.6, 280.3, 50.3 and 203.6 mg/L, which decreased to 405.6, 275.3, 32.6 and 102.3 mg/L in TS and to 368.5, 118, 20.4 and 98 mg/L in PW respectively. Magnesium and bicarbonates in municipal RS were 19 and 120.7 mg/L, which decreased to 10.7 and 86.7 mg/L in TS and to 10 and 82.1 mg/L in PW respectively. The decrease in average concentration of the physico chemical parameters of the TS in relation to that of RS in the present study was because of extended aeration activated sludge treatment (Balluz et al. 1977). Fatma et al. (1998) reported a decrease in physico-chemical concentration in treated wastewater used for irrigation in Egypt.

Plant Growth

One of the ways to reduce the pollution of the receiving water bodies due to the municipal sewage is its optimum reuse in irrigation in horticulture and tree plantations. Tomato plants grown with municipal untreated and treated sewage showed highest growth performance. This is probably due to the increased nutrients present in the sewage, the nutrient concentration of municipal sewage being closely related to the growth parameters ($R^2 = 0.67$). The average height of tomato plant prior to the irrigation with municipal RS, TS and PW were 14.5 $\pm$ 2.05, 13.1 $\pm$ 3.2 and 10.9 $\pm$ 1.1 cm in height respectively, which after a month of irrigation with municipal RS, TS and PW increased to 38.9 $\pm$ 4.5, 35.2 $\pm$ 3.7 and 31.3 $\pm$ 3.9 respectively, after two months of irrigation to 78.1 $\pm$ 7.9, 67.7 $\pm$ 4.3 and 65.3 $\pm$ 6.5 cm respectively, and after three months of irrigation to 98 $\pm$ 7.4, 85.8 $\pm$ 6.9 and 78.4 $\pm$ 6.6 cm, respectively (Fig. 1). ANOVA analysis showed significant difference between the treat-

Table 1: Mean concentration of water quality parameters (January-March 2006) of municipal RS, TS, PW of Kalpakkam township.

Physico-chemical parameters	Raw sewage	Treated sewage	Potable water
Temperature (ºC)	27.8	27.2	27
pH	7.1	6.8	6.73
Electrical Conductivity (μS/cm)	747	630	613
TDS (mg/L)	481.6	405.6	368.5
TSS (mg/L)	375.3	58	4
Total Hardness (mg/L)	203.6	102.3	98
Chloride (mg/L)	280.3	275.3	118
Sulphate (mg/L)	64	50	22
COD (mg/L)	436	214	133.4
BOD (mg/L)	240.6	24.3	6
Ca (mg/L)	50.3	32.6	20.4
Mg (mg/L)	19	10.7	10
Sodium (mg/L)	166.3	70.9	41.2
Potassium (mg/L)	58	31	10
Bicarbonates (mg/L)	120.7	86.7	82.1
Total alkanity (mg/L)	234	103	101.4
Nitrates (mg/L)	45.6	18	14.5
Phosphates (mg/L)	1.2	0.36	0.21
Carbonates (mg/L)	10.8	2.9	0.62

Table 2: ANOVA analysis of length of the plants, number of branches and leaves of the tomato plant across different irrigation treatments.

Source of Variation	*df*	*SS*	*MS*	*F*	*P-value*	*F-crit*
Height of the plant:						
Between treatments	2	4347.011	2173.506	156.5562	0.000159	6.944276
With in treatment	2	303.7097	151.8548	10.93801	0.023896	6.944276
Error	4	55.5329	13.88323			
Total	8	4706.254				
Number of Branches/plant:						
Between treatments	2	174.5617	87.28086	51.84051	0.00138	6.944276
With in treatment	2	44.85802	22.42901	13.32172	0.017039	6.944276
Error	4	6.734568	1.683642			
Total	8	226.1543				
Number of Leaves/plant:						
Between treatments	2	4056.747	2028.373	67.51174	0.000828	6.944276
With in treatment	2	1561.414	780.7068	25.9848	0.005108	6.944276
Error	4	120.179	30.04475			
Total	8	5738.34				

ments and within the treatments with respect to the height of the plants (Table 2). According to Nicola Rodda (2005), there was a consistent increase in tomato plant height and yield when the crops were irrigated with the grey water, as compared with municipal potable water. Sahai et al. (1983) reported better growth of chickpea cultivars at 6.25% effluent concentration, which may be due to the growth-promoting effect of nitrogen and other mineral elements present in the effluent. Ahmad et al. (2003) have reported that sugar-cane growth was better when irrigated with treated wastewater from an oil refinery than the control i.e., ground water.

The average total number of branches of tomato plants prior to the treatment with irrigated municipal RS, TS and PW were 5.5 ± 0.5, 5 ± 0.5 and 4.8 ± 0.3 respectively, which after one month of irrigation, increased to 10.6 ± 2.2, 8.8 ± 0.8 and 8 ± 0.8, after two months of irrigation to 19 ± 5.4, 14 ± 2.1 and 13.5 ± 1.7, and after three months of irrigation to 24.3 ± 4.8, 18 ± 2.5 and 17.3 ± 1.1 respectively (Fig. 2). The average total number of leaves of tomato plant prior to the treatment with irrigated municipal RS, TS and PW were 33.1 ± 7.1, 26.3 ± 5.3 and 23.1 ± 3.6, which after one month of irrigation, increased to 55.8 ± 13.1, 41.5 ± 7.4 and 34.8 ± 5.2, after two months of irrigation to 90.5 ± 14.8, 61.3 ± 3.5 and 60.1 ± 5.9, and after three months of irrigation to 119.8 ± 12.01, 86.6 ± 7.2 and 81.6 ± 5.5 respectively (Fig.3). ANOVA analysis showed significant difference between the treatments and within the treatments with respect to the number branches and of leaves per plant (Table 2). The increase in the number of branches and leaves of saplings grown in municipal sewage was probably because of relatively more nutrients present in the sewage compared to that of PW.

Average numbers of tomatoes per plot irrigated with the municipal RS were 17.8 ± 2.1 (Fig. 4) weighing 800 ± 160.7 g (Fig. 5). However, the average number of tomatoes per plot irrigated with the TS decreased to 14.6 ± 2.9 (Fig. 4) weighing 508 ± 83.7 g (Fig. 5) and that of tomatoes irrigated with PW decreased to 9.3 ± 2.7 (Fig. 4) weighing 400 ± 86.6 g (Fig. 5).

The average length of roots of tomato plants prior to the treatment with municipal RS, TS, and PW was 6.35 ± 0.6, 5.9 ± 1.1 and 5.3 ± 1 cm respectively, which after three months of irrigation with municipal RS, increased to more than six folds (40.5 ± 1.5 cm), with TS increased more than five folds (30.5 ± 0.7 cm) and with PW increased to more than five folds (26.9 ± 3.4 cm) (Fig. 6). The availability of water and nutrients probably showed positive effects on root growth (Singh & Bhati 2003).

In corroboration with present findings Erfani et al. (2001) showed that utilization of treated municipal wastewater has increased tomato yield as compared to irrigation with the well water. Albulbasher et al. (1998) reported that the plots irrigated with wastewater along with fertilizer has the higher yield followed by the plot irrigated with freshwater and fertilizer with respect to the number of fruits and their total weight. Feign & Kipnis (1980) reported that application of sewage effluents was beneficial in increasing the crop yield and reducing fertilizer requirement.

Wastewater is a rich source of plant nutrients. Intizar Hussian et al. (2002) showed that the impact of wastewater irrigation on yield varies from crop to crop. If the crops are undersupplied with essential plant nutrients, wastewater irrigation will act as a supplemental source of fertilizer thus increasing crop yields. Alternatively, if plant nutrients delivered through wastewater irrigation result in over supply of nutrients, yields may be negatively affected. In the absence of any chemical fertilizer application, wastewater nutrients will act as a sole source of fertilizer, savings in fertilizer cost. Thus, from an economic standpoint wastewater irrigation may have a three-fold effect on crops: (i) higher yield, (ii source of irrigation water, and (iii) fertilizer value. Braatz & Kandiah (1996) reported that experiments have repeatedly demonstrated an increased productivity of crops when irrigated with wastewater as compared with clean water. These nutrients represent a resource of considerable value when compared with the equivalent cost of fertilizer. The application of wastewater at rates that ensure a balance between nutrient input and plant uptake will promote optimal plant growth while limiting the risks of pollution.

RECOMMENDATIONS

Expansion of urban population and increased coverage of domestic water supply give rise to higher

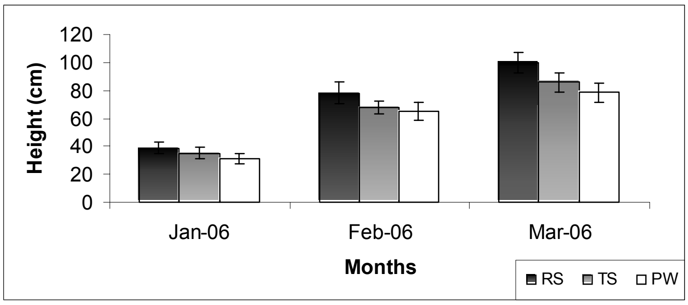

Fig.1 Variation in average plant-height (cm) across different treatment (RS, TS and PW) during the crop period.

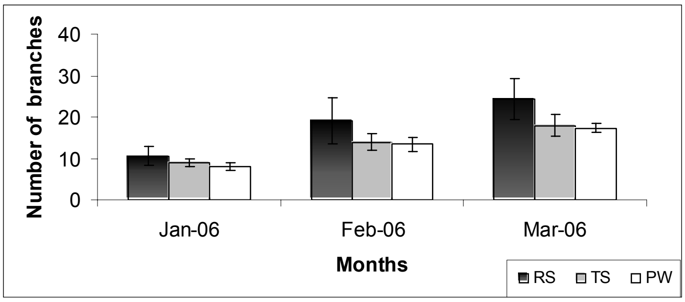

Fig.2 Variation in average number of branches across different treatments (RS, TS and PW) during the crop period.

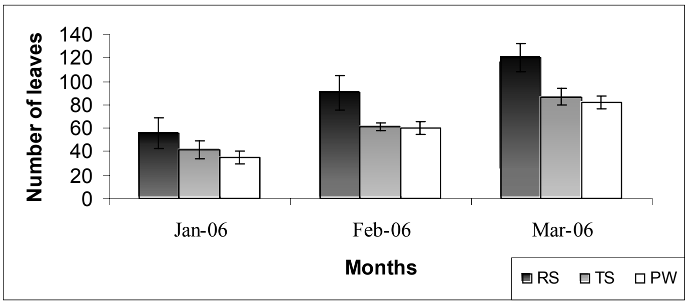

Fig.3. Variation in average number of leaves across different treatments (RS, TS and PW) during the crop period.

quantities of municipal wastewater. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose off the municipal wastewater safely as well as beneficially. It is advantageous to consider reuse of treated sewage. Use of wastewater in agriculture growing vegetables such as tomatoes could be an important consideration when its disposal is planned in arid and semi-arid regions.

Proper planning of urban wastewater reuse alleviates surface water pollution problems; it not only conserves valuable water resources but also takes advantage of the nutrients contained in sewage to grow crop plants. The nitrogen and phosphorus content of sewage might reduce or eliminate

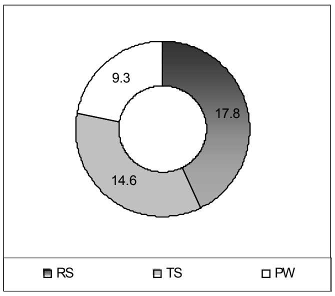

Fig.4. Variation in average number of tomatoes across different treatments (RS, TS and PW) at the end of the crop period.

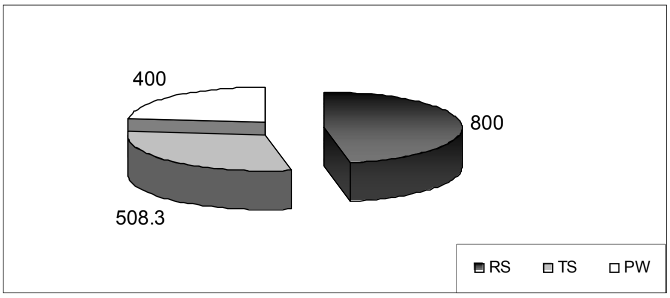

Fig.5. Variation in average weight of tomato yield (g) across different treatments (RS, TS and PW) at the end of the crop period.

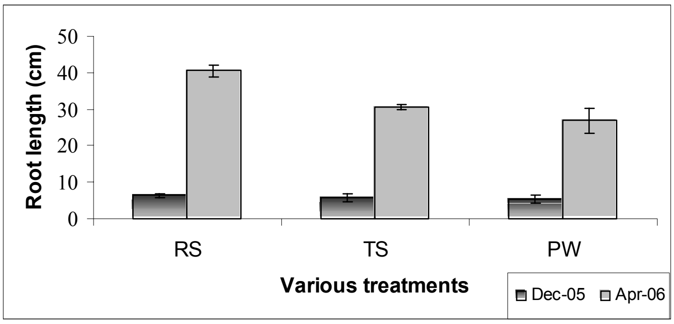

Fig.6. Variation in average root length (cm) across different treatments (RS, TS and PW) at the beginning and end of the crop period.

the requirements for commercial fertilizers. The cost of transmission of effluent from inappropriately sited sewage treatment plants to distant agricultural land is usually prohibitive.

If people have no choice but to use municipal sewage to irrigate crops we suggest a resting period of at least one month between last irrigation and harvest. Importantly, users should take appropriate hygienic precautions when handling the municipal RS or TS, and wash and preferably cook the produce before consumption. Nevertheless, municipal RS or TS reuse shows great potential. Further research would answer the remaining questions to turn this pollutant into an important resource.

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