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Effects of treated municipal wastewater irrigation on soil properties, switchgrass biomass production and quality under arid climate

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ABSTRACT

Ongoing severe drought and increased demand for freshwater by municipal and industrial sectors have reduced the freshwater availability for agriculture in the far west Texas region. The region has enormous potential for developing alternative water sources for a bioenergy crop that requires less water and can grow on saline soils. In addition to improving farm income, this can help in producing 137 billion liters of bio-based transportation fuels goal set by the U.S. Congress by the year 2022. This study evaluated switchgrass (*Panicum virgatum* L.) performance under treated urban wastewater irrigation on salt affected soils amended with gypsum and polymer using soil columns prepared from a salt affected land over six years under greenhouse conditions that mimicked the climatic conditions of the study region. Results indicated that switchgrass produced appreciable biomass even under highly saline and sodic conditions. Qualities of biomass under treated urban wastewater were comparable to that produced under freshwater irrigation. Expectedly, soil salinity increased with time at a greater rate under wastewater irrigation than freshwater. Soil SAR values were below threshold when adequate Ca was available to counter sodicity. In addition irrigation with treated wastewater improved nitrogen and potassium status in the root zone. This can reduce of cost of fertilization and increase farm profitability.

1. Introduction

El Paso County is located in the west Texas in USA and it is a part of the extremely arid middle Rio Grande river basin. Agriculture in the region is totally dependent on irrigation water delivered by the Rio Grande Project. It is estimated that about 80% of the cropped area in the Rio Grande project area is affected by varying degrees of salinity (Ghassemi et al., 1995). Middle Rio Grande basin like many arid regions of the world is facing rapid increase in water demands due to rapid population growth (over 2 million people live in the region) and urbanization. Ongoing severe drought and reduced snowpack impacting river flows have resulted in declining freshwater availability. This has restricted river water allocation by the irrigation districts and forced farmers to use brackish groundwater and treated municipal wastewater for meeting irrigation requirements. During some years only 30–60 cm irrigation was made available by the irrigation district in El Paso, mostly supplied in the form of treated municipal water or blended with river water. The cropping pattern in the region is dominated by cotton (*Gossypium hirsutum*), alfalfa (*Medicago sativa*) and pecan (*Carya illinoinensis*). Cotton is planted in nearly 50% of the cropped area and requires about 86 cm of irrigation. Both alfalfa and pecan crops require about 153 cm of irrigation and are considered salt sensitive. Since the amount of water supplied by irrigation district was too low to grow even cotton during drought years, almost all of fields were abandoned.

The region has enormous potential for marginal quality water irrigation to produce bioenergy crops for a greater farm returns. For example, only 13% of the 7894 ha meter of treated urban wastewater in El Paso County in west Texas is reused every year (EPWU, 2011). In addition, far west Texas has about 100,000 ha of idled or abandoned farmland that can be irrigated with brackish groundwater available in the region for bioenergy crops production. If a suitable bioenergy crop can be produced on these abandoned lands, in addition to improving farm income, it also helps in bridging the huge gap between the mandated Renewable Fuels Standards (RFS2) goal set by the U.S. congress to use at least 137 billion liters of

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Table 1
Long-term climatic data for the study area.

Month	Max Temp. °C	Min Temp. °C	Avg Temp. C	Relative Humidity %	Precipitation cm	Potential Evapo-Transpiration cm day^{-1}
January	15.7	−3.2	6.2	53.3	0.711	0.234
February	17.7	−1.4	8.2	47.0	0.889	0.368
March	21.3	2.0	11.7	39.6	0.711	0.521
April	26.6	6.9	16.8	37.6	0.483	0.671
May	31.4	11.0	21.2	38.4	0.508	0.759
June	35.8	16.2	26.0	40.2	1.473	0.833
July	35.4	19.1	27.3	51.9	3.505	0.744
August	34.4	17.6	24.9	55.5	3.353	0.699
September	31.9	13.6	22.8	55.1	2.667	0.592
October	27.1	6.8	16.9	53.4	1.346	0.442
November	20.0	0.4	10.2	51.3	0.610	0.300
December	15.4	−3.4	6.1	54.9	0.660	0.201
Annual				48.1	16.916	193.751

bio-based transportation fuels by 2022 and the current capacity of about 60 billion liters of biobased fuels (USDA, 2015).

Switchgrass (*Panicum virgatum* L.) has been identified as a strong candidate for bioenergy production because of its favorable attributes such as ability to grow on different soils under a variety of environmental conditions (McLaughlin et al., 2006). Its many beneficial attributes and wide distribution can make switchgrass a suitable crop for the arid southwest region. Studies have reported that lowland ecotypes have late maturity, thick stems and dense bunch enabling them to better adapt to southern latitudes of the study site (Casler et al., 2007). Among the lowland ecotypes "Alamo" cultivar has been reported to have superior adaptation range spanning numerous USDA hardiness zones (Sanderson et al., 2007; Casler and Vogel, 2014). Alamo is well adapted to Texas conditions and limited studies have reported that it is salt tolerant among lowland ecotype cultivars (Kiniry et al., 2012; Liu et al., 2014). However, its performance with marginal quality water irrigation on saline soils under arid conditions is not well studied.

Developing beneficial and economically feasible strategies to utilize these marginal quality waters will benefit the region while providing bioenergy for our growing population. Therefore in this study "Alamo" switchgrass was selected to understand effects of marginal quality treated wastewater irrigation on crop performance and soil salinity/sodicity under greenhouse conditions. The objectives of this study were to evaluate (i) performance of Alamo switchgrass cultivar under marginal quality water irrigation under extremely arid conditions of far west texas simulated in the greenhouse, and (ii) effects of marginal quality water irrigation on soil salinity and sodicity to develop suitable salinity management practices.

2. Materials and methods

2.1. Study area and experimental design

The experiment was conducted under greenhouse conditions that simulated long-term climate of El Paso County in the far west Texas (Table 1). The long-term annual average values for the study area are: precipitation~ 17 cm; potential evapotranspiration ~194 cm; maximum temperature ~35.8 °C; minimum temperature~ −1.4 °C, relative humidity of 48.1%, wind speed of 1.21 m/s and solar radiation 19.78 MJ m^{-2} day^{-1}.

Split plot experimental design was used to evaluate the effects of two water qualities (wastewater and freshwater) on three soil treatments (no amendments, gypsum, and polymer) at four soil depths (as repeated measures) replicated three times. Two water qualities consisted of (i) Treated wastewater (TWW) and (ii) freshwater (greenhouse tap water derived from Rio Grande River, used as a control) (Table 2). The source of treated wastewater was the nearby Roberto Bustamante Wastewater treatment plant that receives municipal wastewater. The treatment process consisted of screening, de-gritting, pre-aeration, primary settling, aeration, secondary settling, and disinfection.

A total of 18 soil columns were used to evaluate switchgrass performance in the greenhouse. Soil collected from a nearby abandoned cotton field (35°39′34.6″N & 106°16′9.54″W) at four depths (0–15, 15–30, 30–45 and 45–60 cm) was used to construct 18 columns. As a first step, soil cores were collected from four depths (0–15, 15–30, 30–45 and 45–60 cm) at three random locations in an abandoned salt affected cotton field to determine bulk density (Grossman and Reinsch, 2002). Then, about 3 m × 3 m area close to bulk density sampling location was used collect soil samples for constructing soil columns. Soil samples for each of the depths

Table 2
Selected chemical properties of the irrigation waters used in the study.

Parameters	Tap water	Treated Wastewater
Electrical Conductivity EC_e (dS m^{-1})	1.4 ± 0.4	2.6 ± 0.3
pH	7.1 ± 0.4	7.3 ± 0.4
SAR (mmol$^{1/2}$ L$^{-1/2}$)	4 ± 1	9.3 ± 0.4
Ca (mg L^{-1})	54 ± 21	66 ± 10
Mg (mg L^{-1})	13 ± 4	17 ± 4
Na (mg L^{-1})	127 ± 14	328 ± 14
K (mg L^{-1})	12 ± 2	32 ± 5
B (mg L^{-1})	0.08 ± 0.10	0.26 ± 0.13
Cl (mg L^{-1})	164 ± 93	465 ± 22
NH_4 (mg L^{-1})	–	3.86 ± 2.39
NO_3 (mg L^{-1})	6 ± 3	18.1 ± 5.1
SO_4 (mg L^{-1})	101 ± 51	201 ± 33
BOD 5 (mg L^{-1})	–	3.22 ± 0.86
Fecal Coliform (CFU/100 mL)	–	3.29 ± 2.62