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RESEARCH PAPER

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The effect of the use of sewage water from the treatment plant in Makkah Al Mukarramah on the growth and productivity of forage crop in Sudan grass (Sorghum *sudanensis* L.)

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Key words: Makkah city treated sewage water, Sudan grass.

Abstract

This experiment was carried out at the agricultural research station of King Abdul Aziz University in Hada al-Sham northeast of Jeddah to study the effect of irrigation with mixed sewage water from Makkah City treatment plant on growth components and fresh forage yield of Sudan grass during 2016 season. The experiment was carried out using the design of three random replications. The mixed water treatments are (100% normal water + zero sewage water, 75% normal water + 25% sewage water, 50% ordinary water + 50% sewage, 25% normal water + 75% sewage, 0% normal water + 100% sewage). The area was divided into three replicates each with 5 plots (5 x 5m) to represent irrigation treatments. Irrigation with 75% treated sewage water + 25% normal water and 50% treated sewage water + 50% normal water significantly enhanced and increased all studied growth components and forage yield of Sudan grass crop compared to other treatments, with no significant difference between them followed by 100% treated sewage water. Irrigation with 100% normal water gave the least means of the studied parameters. Irrigation with 75% treated sewage water + 25% normal water and 50% treated sewage water + 50% normal water can successfully be used in irrigating Sudan grass.

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Introduction

Water availability for irrigation is needed badly particularly in countries like Saudi Arabia. There is an increased demand for using wastewater in agriculture sector, and this trend of using treated wastewater in agriculture is now gaining tremendous popularity throughout the world. Under use of wastewater in agriculture as an alternative to fresh water, this will liberalize fres water to provide drinking water for communities. Sudan grass is a fodder crop that have proved successful under dry land conditions represented in lack of water and high temperature. This plant is characterized by its high nutritional value, which contains 5% protein and 55% carbohydrate of wet weight, and water stress reduced Sudan grass plant length, leaf area and total yield (Benneit and Sullivan, 1981). Increased irrigation water gave increase in the surface area of the leaves and plant height of Sudan grass (Rosenthal *et al.,* 1987; Scarascia *et al.*, 1983). The higher protein content in the Sudan grass plant increases with the increased rate of irrigation (Cabiel and Ashcroft, 1972). Research work on application of Wastewater effluent in agriculture revealed that on irrigating plants with this treated water plant fresh and dry weight, yield, content of nitrogen and phosphorus increased as well as many other nutrient elements (Akponikpe *et al.*, 2011). When soybean was irrigated with secondary treated municipal wastewater and well water yield was increased up to 354 and 205kg/ha more than the control and well water, respectively (Cordonnier and Johnston, 1980). Under irrigation of wheat and alfalfa with treated sewage water their yield increased by almost 11% and 24% respectively compared to irrigation with normal water (Al-Abdulqader and Al-Jaloud, 2003). Many vegetables were grown under treated wastewater like corn, potato, lettuce, olive trees, and alfalfa and their yields increased significantly compared to irrigation with normal water (Munir and Mohammed, 2004; Kouraa *et al.*, 2002; Lopez *et al.*, 2006; Jasim and Abdul, 2010).

Using treated sewage water in agriculture will not cause bad effects on crops under controlled conditions, (Najafi *et al.*, 2003, Jimenez, 2005, Munir and Ayadi 2005, Esmailiyan *et al.*, 2008 and Zavadil, 2009). Irrigation with treated or raw sewage water is practiced in in developing countries and large areas are cultivated and irrigated (Dreschel *et al.*, 2002). Treated sewage water contains inhomogeneous organic matter and most of the solid organic substances is protein while the soluble organic substances contain low percentages of protein (Helfgott, 1970). The inorganic substances in treated sewage water mostly are salts of nitrogen and phosphorus which are important plant nutrients, and the N is present as ammonium nitrogen (NH_4-N) (Russel *et al.* 1970). Treated sewage water also contains salts as chlorides, sulphates, sodium bicarbonate, calcium and magnesium, and these salts are not affected by secondary treatment, but remain in water (Takashi, 1985). Takashi, (1985) determined the following metals in soil irrigated with sewage water Cu (8.9-86.5mg/kg), Cd (0.86-5.07mg/kg), Pb (18.1-131.7mg/kg), Zn (101-235mg/kg). When some vegetables were grown under arid conditions using wastewater irrigation the wastewater quality and irrigation system and their interactions imposed significant impact on their yield, yield components and quality (Balkhair *et al.*, 2014). Irrigation with 60% and 80% wastewater under sub-surface irrigation system produced the highest yield and yield components in both seasons.

Treated sewage water also contains coliform and fecal bacteria, and the level of these bacteria (fecal coliforms) for irrigation should not exceed (1000/100ml) as suggested by many international bodies, like the Environmental Protection Agency in America (EPA 1973; WHO, 1989). Treated wastewater is an important and cheap water source that can be used in agriculture, especially in dry countries, and sewage irrigation has increased total nitrogen content and available phosphorus (Mitra and Gupta (1999). AL-Wabel, *et al.* (1998) suggests that treated wastewater can be used to produce crops without any adverse effect on plants, and they recommend the use of treated wastewater in crop production due to its nutrient content. Excessive contents of heavy metals in crops irrigated with wastewater have not been reported (Zavadil 2009). Whenever used for irrigation treated sewage water imposes its significant effects on growing plants, vegetables or crops due to its high nutritive quality (Bashey *et al.*, 2007). The objective of this study was to investigate the effect of irrigating Sudan grass fodder crop with treated sewage water from Makkah sewage treatment plant diluted with fresh water up to five levels. The study was to test the effects of these five levels of dilutions on the growth parameters of the crop, fresh and dry weight, stem length, leaf area index, content of heavy metals and macro-elements.

Materials and methods

Design

Randamized complete design with three replications was used. The experimental area was divided into 3 replicates each is represented by 5 plots (5x5 m)to represent irrigation treatments,

Irrigation treatment:

Spray irrigation was used in this experiment, where two types of irrigation water were used (irrigation water from Huda Al-Sham station and treated wastewater) and were mixed with different rates to obtain five irrigation parameters as follows:

Normal Water Treated Water
First Treatment 100% 0%
Second treatment 75% 25%
Third treatment 50% 50%
Fourth treatment 25% 75%
Fifth Treatment 0% 100%

The amount of water added to each irrigation treatment was fixed based on the water consumption of the crop. Where water consumption is calculated using the following formula:

ETc = Kc X ETr

Where as:

ETc: Water Consumption of Crop (mm/day)

ETR: Water Consumption of Reference Crop (mm/day)

Kc: Crop coefficient

The water consumption values of the reference crop for the study area were used from Mashat *et al.* (2000). The values of the cropping coefficient for alfalfa and Sudan plow are used in the paper published by FAO in paper No. 56 (Allen *et al.*, 1998). Irrigation was determined based on the physical properties of the soil in the study area, which determines the amount of water available to the plant in the soil and based on the knowledge of the amount of daily consumption of the plant.

Planting method:

The soil was ploughed, levelled, and seeds were dispersed at rate of 50/ha. Phosphorus was added in the form of Super Phosphate (P_2O_5 46%) at a rate of 150kg/ha. Potassium was added in the form of Potassium Sulphate (K_2SO_4 50%) at rate 100kg / ha. Nitrogen fertilizers were added in the form of urea (N 46%) in batches at a rate of 109kg urea / ha where the first batch was added after 15 days of planting. The other batch will be added at the same rate after each share. The trial was carried out on 1/4/2016 corresponding to 22/2 /1437H.

Plant Samples collection:

3 cuttings from Sudan's grass were taken. Five full plants were randomly selected from each treatment before each cutting, and plant length was taken. The fresh weight of the total vegetative growth and its components of leaves and stems was estimated using a frame area of one square meter so that it was tossed three times in each plot randomly and then the plants within the frame were cut at a height of 5cm from soil.

The wet yield per hectare was calculated from the total weight of the plants from the whole area of the experimental unit (25m 2).

Results

First: Effect of cuttings on growth components and total fresh forage yield of Sudan grass Statistical analysis data in Table (1) show the significant differences between cuttings on all the studied traits except the leaf area index.

Plant height

Table (2) shows that the first cutting gave significantly the highest plant height (133.1 cm) than the second (111.99 cm) and the third (110.19 cm).

Table 1. statistical analysis of variance of plant characteristics of Sudan grass under cuttings and irrigation water type.

	DF	Plant height (cm)	Leaf area (cm^2)	Fresh weight (gm/ cm^2)			Total fresh wt.
				Leaves	Stem	Vegetative growth	
Rep.	2	1331.50	10.55	702213.8	2912145.9	6166397	393.9
cuttings	2	2593.56**	6.52	8665395**	41768694**	88468160**	6589**
Water type	4	7566.31**	44.72**	1586407*	6241362.4	13919475	1120**
Irrig.xcut	8	497.92**	14.84**	197694	2724859.	5157037	272*
LSD	28	100.71	3.97	395214	2283388	4367911	10.51

* The averages followed by the same letter do not differ significantly from each other at a significant level 0.05.

Leaf Area Index

The means in Table (2) show that there are no significant differences between the three cuttings in the leaf area index, which ranged from 5.06 in the first cutting to 3.89 in the second cutting.

Fresh weight of Sudan grass shoot system

Leaves fresh weight (gm/m²)

The means of the cuttings in Table (2) show that the first cutting was significantly higher in leaves fresh weight per m² where it gave 2131.5gm / m² while the second and the third were significantly equal in weight with an average of 825.9gm / m ² and 804.5 gm/ m2respectively.

Stems fresh weight (mg / m²)

Also, as in the case of leaves fresh weight, stem weight in the first cutting was the lowest weight per square meter with significant difference than the rest of the cuttings, where it gave 4670.6gm /m ² while the second and the third gave 1756.6 and 1804.7gm / m², respectively, as shown in Table (2).

Total fresh weight of shoot growth (gm / m²)

Results of average fresh weight of shoot system under the three cuttings (Table 2) showed that the first cutting was significantly higher than the second and the third where it gave 6802.2g/m ² compared to 2609.2 and 2582.5g/m² respectively for the second and third.

Total fresh fodder yield (tons/ha)

The results of the comparison of the means of cuttings (Table 2) show that the first cutting was significantly higher with 54.12tons / ha compared to the second 28.21tons / ha and the third 27.45ton / ha.

Table 2. means of growth components and yield of Sudan grass under cuttings.

Treatment	Plant height (cm)	Leaf area (cm^2)	Fresh weight (gm/ cm^2)			Total fresh yield t/ha
			Leaves	Stem	Vegetative growth	
First cut	133.81a	4773.9a	2131.5a	4670.6a	680.2a	54.12
Second cut	111.99b	4660.2a	825.9b	1756.6b	2609.2b	28.21
Third cut	110.19b	3793.5b	804.5b	1804.7b	2582.5b	27.45
LSD	7.5	1039.4	470.22	1130.3	1563.2	9.11

*The averages followed by the same letter (letters) do not differ significantly from each other at a significant level 0.05.

Second: Effect of irrigation water quality on Sudan grass

Plant length

Statistical analysis data in Table (1) show significant differences between the irrigation water treatments of all the studied traits. While interaction between cuttings and irrigation water treatments gave no significant effect except in the leaf area index and in the total fresh forage yield. The average results on plant height (table 3) show that irrigation of Sudan grass with water consists of 75% drainage water + 25% normal water gave the highest average of 153.71cm followed by 50% drainage + 50% normal water with an average of 129.73cm and irrigation with 100% sewage water with 126.33cm while irrigation treatment with 100% normal water gave the shortest plants 75.84cm.

Leaf Area Index

The average of the leaf area index under the influence of irrigation water coefficients shows that the addition of high-quality wastewater or irrigation with 100% sewage water was significantly superior to irrigation with 100% normal water. The averages as shown in table (3) are as follows: 7.52, 5.86, 3.99, 2.27, 2.29cm², for 75% sewage water + 25% normal water, 50% sewage water + 50% normal water, irrigation with 100% sewage water, irrigation with 25% sewage water + 75% normal water and with 100% normal water respectively.

Leaves fresh weight (gm / m²)

Table (3) shows that irrigation with 75% sewage water + 25% normal water or 50% wastewater + 50% normal water gave the highest fresh weight of leaves and a significant difference from the rest of the treatments while irrigation with normal water only and 25% sewage water + 75% normal water gave the least leaf fresh weight in / m 2.

Stem fresh weight (gm / m²)

Irrigating Sudan grass with wastewater at any concentration gave significantly higher fresh stem weight than Irrigating with normal water. No irrigation differences between wastewater concentrations with each other, while irrigation treatment of the normal water differed significantly (Table 3).

Total fresh weight of shoot growth (gm / m²)

Averages shown in Table (3), show that irrigating the crop with concentrations of 100% drainage water, 75% drainage + 25% normal water or 50% wastewater + 50% normal water did not differ significantly from each other in the shoot fresh weight.

The highest shoot fresh weight (5199.7gm/m²) was attained by 25% sewage water + 75% normal water, then 4920.7gm/m² under 50% wastewater + 50% normal water, and 4222.1gm/m² under 100% sewage water.

Total fresh forage yield (tons / ha)

Comparison of averages of the total fresh yield of Sudan grass per hectare in table (3) shows that irrigation with 100% sewage water or 75% sewage water + 25% normal water or 50% wastewater + 50% normal water gave the highest yield with productivity equal to 41.63, 50.41, 48.86tons / ha respectively and significantly superior to irrigation with 25% sewage + 75% normal water (35.78tons / ha) and irrigation with 100% normal water with the least average yield (22.96 tons / ha).

Table 3. Means of growth components and yield of Sudan grass under different irrigation water types.

Treatment	Plant height (cm)	Leaf area (cm²)	Fresh weight (gm/ cm²) Leaves	Stem	Vegetative growth	Total fresh yield
100% normal water	75.48d	2.29c	681.3c	1406.2b	2087.6b	22.96c
75% sewage+25% normal water	107.7c	2.27c	1020.bc	2540a	3560ab	35.78b
50% sewage+50% normal	129.73b	5.42b	1573ab	3347.7a	4920.7a	48.86a
75% sewage + 25% normal	153.71a	7.52a	1723.3a	3746.a	5199.3a	50.41a
100% sewage water	126.33b	3.99bc	1272.2b	2950a	4222.2a	41.87b
LSD	9.69	1.92	607.05	1459.1	2018.1	10.1

*The averages followed by the same letter (letters) do not differ significantly from each other at a significant level 0.05.

Disscusion

From the results obtained from this study different cuttings of Sudan grass fodder crop under these treatments showed significant variations in plant height, fresh leaves weight, fresh stems weight, fresh vegetative shoot growth. The first cutting was superior and dominated all other cuttings giving the highest plant height, leaf area index (LAI), fresh leaves weight, fresh stem weight, fresh shoot vegetative growth and the highest fresh forage yield of Sudan grass. This is most probably due to the fact that the crop has taken out most of its plant nutrients organic and inorganic elements, from the soil and might have caused structural and textural changes in the soil characters which are favorable during the first cut.

Under the influence of irrigation of Sudan grass with five different mixtures of treated sewage water and normal water, the treatments significantly affected the plant yield components, plant height, leaf area index, fresh leaves weight, , and fresh fodder yield. It is clear that irrigation with 75% sewage water + 25% normal water and 50% wastewater + 50% normal water gave significantly the highest means of Sudan grass yield components and fodder yield fresh compared to all other irrigation water treatments, and mostly there is no significant differences between them. They are followed by the treatment 100% sewage water. Irrigation with 100% normal water attained the lowest means of all these parameters.

This is mostly due to the high plant nutrient contents and high organic and inorganic substances in sewage water compared to normal water. These contents enhanced Sudan grass growth thus increasing plant height, leaf area, stem growth, leaves and stem weight, shoot vegetative growth and forage yield compared to irrigation with normal water. These results are in compatible with other results found by other researchers, Lazarova and Bahri, (2005) mentioned that treated sewage water contains elements and metals which are useful to plants thus increasing crop yield.

Mandi and Abissy (2000) working on Sorghum, Kouraa, *et al.* (2002) on potato, Munir and Mohammad (2004) on lettuce, Lopez *et al.* (2006) on alfalfa, irrigated these crops with treated sewage water and found significant increases in yield compared to normal water. Al-Lahham *et al.* (2003) studied the effect of irrigation with a mixture of wastewater and potable water at different rates (100% normal water with zero% wastewater, 50% normal water with 50% wastewater, 25 normal water with 75% wastewater and 0% normal water with 100% sewage) on the productivity of the tomato crop, and found an increase in the productivity of the tomato crop with an increase in the percentage of wastewater in irrigation water particularly 75% of the wastewater and 100% wastewater with no significant differences between them. Bashey *et al.* (2007) conducted a study on the effect of the use of wastewater from the treatment plant in Makkah Al Mukarramah after mixing it with different percentages (0%, 25%, 50%, 75%, 100%) of the irrigation water for alfalfa, and obtained the highest fodder yield from the first cutting and irrigation with 100% treated sewage water dominated all other water mixtures giving the highest alfalfa fodder yield.

Conclusion

Irrigation with treated sewage water mixed with normal water at different rates significantly enhanced and increased growth and forage yield of Sudan grass crop. Irrigating Sudan grass with 75% treated sewage water + 25% normal water and 50% treated sewage water + 50% normal water significantly increased forage yield production of Sudan grass and its components (with no significant difference between them), and also 100% treated sewage water proved to be the best mixtures of sewage water compared to other mixtures and to irrigation with 100% normal water. These sewage effluent mixtures gave the maximum plant height, leaf area index, fresh leaves weight, fresh stem weight, fresh shoot vegetative growth and the highest fresh forage yield of Sudan grass. Sudan grass yield components and fresh forage yield were significantly the highest in the crop first cutting compared to the second and third cut.

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