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Utilization of treated sewage water for forage production

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ABSTRACT

Worldwide, the Treated Sewage Water (TSW) reuse for irrigation purposes has been advocated since it shows substantial economic and agricultural benefits. This study investigates the potentiality and effect of the effluent of the algal sewage treatment plant south of Khartoum on forage production. About 9 million gallons are produced per day, which can be recycled. The study evaluates fodder production in locations 1, which represent long-time application of TSW and location 2 as control. Both locations received normal water and TSW for two consecutive seasons. Forages investigated belong to family Poaceae and cultivars of Sorghum bicolor "Abu Sabaien, Pioneer, Panar and Speed feed". Irrigation by TSW resulted in relatively taller plants, plants of all cultivars looked vigorous and healthy, with less fiber content, high protein values and significantly higher dry yields compared to those irrigated by normal water at 0.05 levels of significance and no symptoms of phytotoxocity were observed. The yield of Pioneer was significantly higher than the rest of the cultivars at 0.05 levels. TSW showed no effect on soil characteristics and no serious pollution probed moreover, can be safely used for the production of fodder crops of the family Poaceae that produced higher yields and better quality.

KEYWORDS

Sewage irrigation, sewage analysis,Sorghum cultivars,orage characteristics,roximate Composition Analysis.

1.Introduction

Domestic wastewater represents a valuable additional source of water for use after adequate treatment. World wide sewage reuse for irrigation purposes has been strongly advocated since it shows substantial economic and agricultural benefits such as providing an extra water source, retaining valuable fertilizers to land to stimulate agricultural production and minimize environmental pollution.

In Sudan, the government and farmers did notice the value of wastewater for their agricultural activities longtime ago; In 1958 the algal sewage treatment plant in Algoz area south of Khartoum was established treating some 3.5 million gallons of wastewater that come from 15% of the population of greater Khartoum. The treated sewage water was used to irrigate 1/3rd of the Green Belt that bound Khartoum city from the south curbing the nuisance effect of sand storms. The belt consisted from *Acacia spp* and *Eucalyptus* plantations on an area of 3218.48 ha. (National Forestry Corporation 1997; Sudan Republic Gazette 1962).

Farmers adjacent to the Green Belt used to apply treated sewage water mixed with normal water for irrigation of fodders and vegetables and they speculated among themselves to the higher yields they got. But its use wasn't encouraged much to the fear of consumers who may oppose eating vegetables produced from sewage farms and they shifted to forage production.

This study aims to investigate the safety of Treated Sewage Water for irrigation of fodder crops. It also investigates the quality and yield of four forage cultivars of the family Poaceae in two locations with the same soil characteristics; a virgin soil that did not receive irrigation with Treated Sewage Water and another that has a long record "30 years" of treated sewage water application.

2. Material and Methods

a. The area of study lies about 15 kilometers south of Khartoum. It runs from the Blue Nile East to the White Nile west, it used to support the Green Belt for varying times since 1962, the longest of which is 30 years to date. Location 1 chosen represent long-time application of treated sewage water and location 2 is an experimental site which of the same soil characteristics but did not receive any irrigation of treated sewage water before. The experiment took place for two successive seasons (August to October 1999 and from February to May in 2000.

a. Soil of location 1 is clay loam with 38% sand, 8% silt and 54% clay and pH 9.0. Soil of location 2 is sandy clay loam with 54% Sand, 17% silt and 29% clay with pH 8.3 and the rest of the chemicals parameters were shown in Table (1).
b. Land was ploughed by the help of tractor in both locations, harrowed and then levelled. The gross plot size was 3 x 3 m in both locations. The layout of the experiment was complete randomized design CRD with two-irrigation regime; normal and treated sewage water. The whole experiment was replicated three times giving a total of 48 plots (Gomez and Gomez, 1984).
c. Certified seeds were obtained from Pioneer company in Khartoum (authorized dealers for distribution of forage seeds). Seed rate was 40 Kg per feddan (95 kg/ha).
d. Normal Water was applied to both locations from a borehole via small channels while the treated sewage water TSW for location 2 was transported from the Sewage Purification Plant by a tanker truck whereas for location 1 was supplied directly from the canal of the TSW. The plots received equal amounts of water. (For the quality of both water types see Table (2).
e. Forage cultivars used in the experiment were cultivars of *Sorghum bicolor* (Abu 70", Pioneer, Speed feed and Panar) denoted by V_1, V_2, V_3 and V_4 respectively. In each plot there were 5 ridges, the four cultivars were sown in the 1^{st} of August on both shoulders of the ridges, ridges were 70 cm apart. No fertilizer was administered in both treatments.
f. Climate of Khartoum State is characterized by seasonally high temperature (average 38^o C) with annual rainfall about 200 mm within 2-3 months/ year (usually August to September)

In each plot, the outer most rows were left as guard rows, the outer two rows were allocated for destructive samples measuring plants constituents, while the middle two rows were left for yield measurements. Sampling and growth measurement were started 40 days after sowing for the following Growth Parameters:

Number of leaves per plant, stem diameter (using vernie), leaf area, leaf/stem ratio and yield. Plants from two segments of 1 meter each were harvested from two middle ridges. The fresh yield was measured in the field and then it was left to dry in the open and the dry weight was recorded, (Watson and Watson, 1954).

Proximate composition analysis was done to determine plants constituents on dry matter basis after preparing the samples according to Standard Methods. Leaves were carefully cleaned and ground to pass through 0.4 mm sieve. Chemicals used in the tests were of analytical grades.

Moisture content was determined by the AOAC method (1984). 2g material was placed in preheated, pre-weighed dishes, each dish with its sample was dried in an oven at 103 ± 2 °C over night. The dishes were transferred to a desicator, left to cool and moisture was calculated. Ash was determined whereby 2 g of the ground sample put in a crucible that placed in a muffle furnace under 600^{o} C then to a desiccator and then let to cool, then measured to determine ash percentage.

Fat was determined by the ether extract method where a clean dry soxhlet flask was accurately weighed; 2 g of the ground oven dried sample was placed into the soxhlet thimble (Extraction Thimble). The thimble was plugged with a cotton wool and subjected to extraction with petroleum spirit (boiling at 60-80 ^{o}C). Fat content was calculated as percentage (Association of Official Analytical Chemists, 1984)

Crude Fiber was determined according to Whitehouse *et. al* (1945) where 2 g of defatted sample was treated successively with boiling solutions of 0.26 N H_2SO_4 and 0.23N NaOH. The residue was separated, washed, dried and ashed at 450^{o} C. The loss of weight corresponds to crude fiber. Crude protein was determined by semi-micro kjeldahl distillation method as described by Pearson (1976) where exactly 0.2 g of the ground sample was digested using 0.8 g catalytic mixture of anhydrous sodium sulphate, 3.5 % copper sulphate and selenium dioxide and 3.5 ml sulphuric acid (conc.) and then distillated with kejeldahl apparatus with aqueous ammonium hydroxide solution and titrated against 0.01 hydrochloric acid and calculated using the equation:

$$N\% = \frac{\text{Titre HCl} \times 0.02 \times 14 \times 100}{\text{Weight of sample g} \times 1000}$$

Crude protein = N% x 6.2

Ash% was determined and by subtraction from 100% to get the organic matter content of the samples. The organic matter percentage denotes the sum of the crude protein, crude fiber, crude oil and nitrogen free extract.

3. Results and Analysis

Soil characteristics of the two locations was recorded initially to be as shown in Table (1)

Parameter	Clay%	Silt%	Sand%	N%	P mq/l	K mg/l	pH paste	EC dS/m $^{-1}$	SAR
Loc 1	54	8	38	0.081	0.356	15.6	9.0	4.2	2.19
Loc 2	29	17	54	0.032	0.315	5.9	8.3	5.19	2.10

Table 1:The results of soil analysis for both locations 1 and 2

Treated Sewage Water, as a result of biological treatment via oxidation ponds, was analyzed and results were presented as averages of 12 months that started on the fourth day of August 1999 the sowing date of the four cultivars. The results of the quality of the treated sewage water TSW (averages of August 1999 to July 2000 values) as well as the normal water N used in irrigation compared to FAO Maximum Recommended Concentrations were shown in Table (2).

The use of Treated Sewage Water and normal water for two seasons to produce forage cutivars of sorghum in both locations; the demonstration farm and the sewage premises field did show differences in the crops performance.

Physical Parameters were measured as well as the chemical analysis of the crops tissues to evaluate the performance of the forage crops irrigated with both waters for two successive seasons.

Table 2: Average characteristics of treated sewage water TSW (averages of August 1999 to July 2000 values) and normal water N used in irrigation compared to FAO Maximum Recommended Concentrations

EC: Electrical Conductivity (in dS/m at 25°)

BOD; Biological Oxygen Demand

SS: Suspended Solids

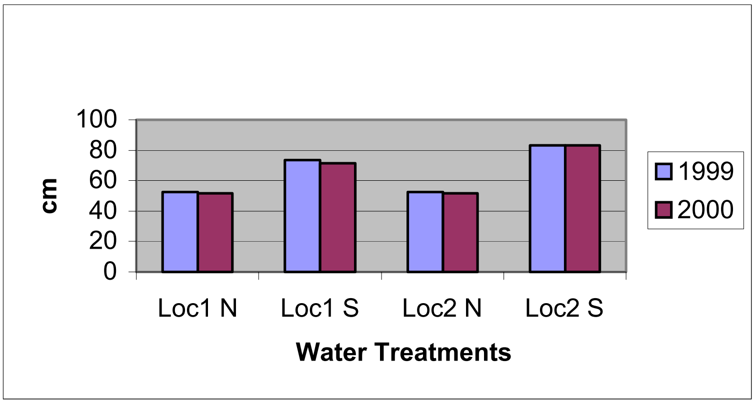
COD: Chemical Oxygen Demand

SAR: Sodium Adsorption Ratio (in molalities)

Parameter	TSW	N	FAO
PH	8.3	7.7	6.5 – 8.5
EC dS/m^{-1}	6.7	2.3	3
Ca mg/l	26	32	400
Mg mg/l	17.2	19.2	60
Na mg/l	86	-	900
HCO_3 mg/l	183	-	600
SO_4 mg/l	76.8	-	1000
Cl mg/l	1.77	12	1100
Cd mg/l	0.02	-	0.01
Cu mg/l	0.04	-	0.1
Fe mg/l	0.7	0.38	5
Mn mg/l	0.03	0.2	0.2
Pb mg/l	-	-	2
Zn mg/l	0.05	-	-
Co mg/l	0.04	-	0.05
Cr mg/l	0.003	0.01	0.1
K mg/l	33.5	-	-
BOD mg/l	82.5	-	-
COD mg/l	133.3	-	-
SS mg/l	62	-	-
DO mg/l	8.5	-	-
NH_3 mg/l	10.9	-	-
NO_3 mg/l	3.5	-	-
SAR	1.9	3.2	15

The forage Crop cultivars cultivated in both locations received normal as well as treated sewage water for two successive seasons. Forages showed variations in their growth and performance. Growth parameters as well as the proximate composition analysis and chemical constituents of the crop tissues were reported for the representative samples.

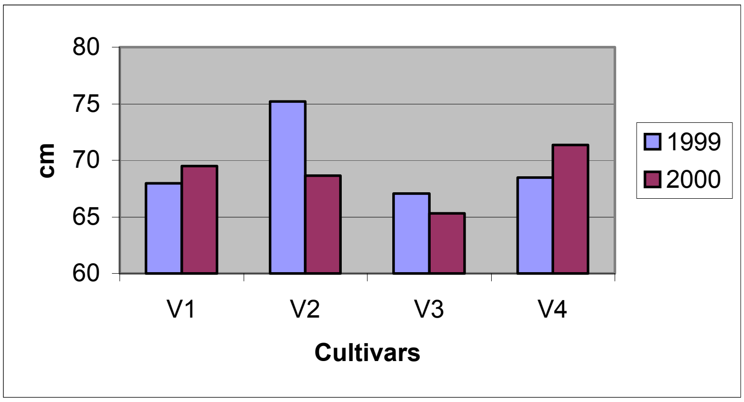
Plant height



Loc 1: Soba Treatment Plant Premises Loc 2: Soba Demonstration Farm

N: Normal Water *S: Treated Sewage Water*

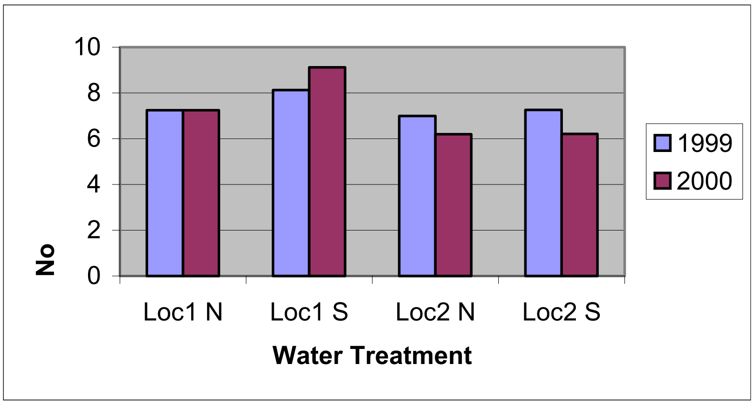
Figure 1a:Effect of water quality on plant height (cm) in seasons 1999/2000



V1: Sorghum bicolor "Abu 70", V2: Pioneer, V3: Speed feed & V4: Panar

Figure 1b:Effect of cultivars on plant height (cm) seasons 1999/2000

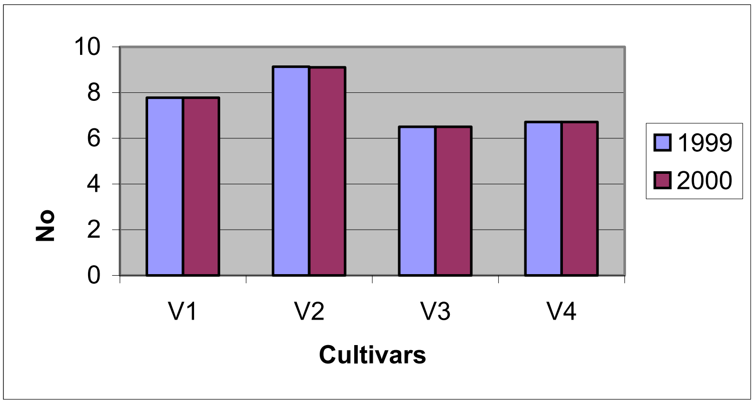
Number of Leaves per plant:



Loc1: Soba Treatment Plant Premises *Loc2: Soba Demonstration Farm*

N: Normal Water *S: Treated Sewage Water*

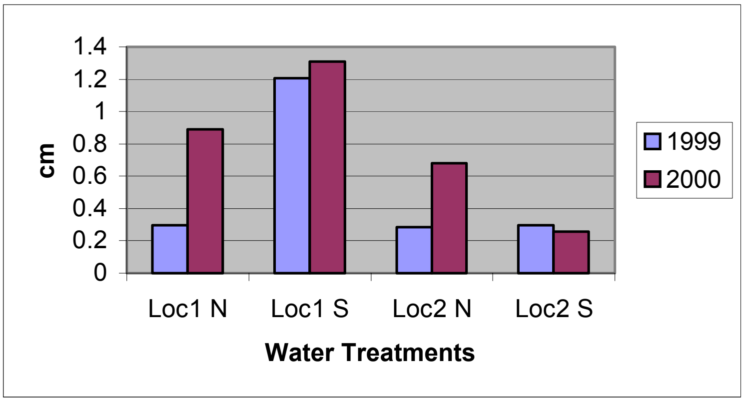
Figure 2a: Effect of water quality at different growth stages on number of leaves during seasons 1999/ 2000



V1: Sorghum bicolor "Abu 70", V2: Pioneer, V3: Speed feed & V4: Panar

Figure 2b: Effect of Cultivars on Number of Leaves during seasons1999/2000

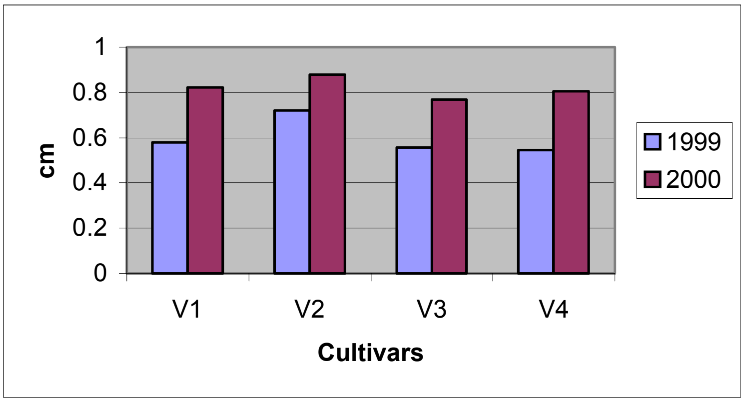
Stem Diameter (cm)



Loc1: Soba Treatment Plant Premises *Loc2: Soba Demonstration Farm*

N: Normal Water *S: Treated Sewage Water*

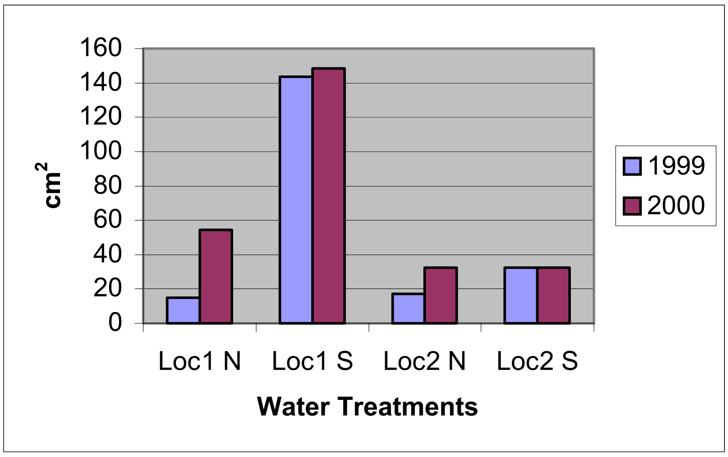
Figure 3a: Effect of Water Quality at different growth stages on stem diameters during seasons 1999/ 2000



V1: Sorghum bicolor "Abu 70", V2: Pioneer, V3: Speed feed & V4: Panar

Figure 3b: Effect of cultivars on Stem Diameters (cm) during season's 1999/ 2000

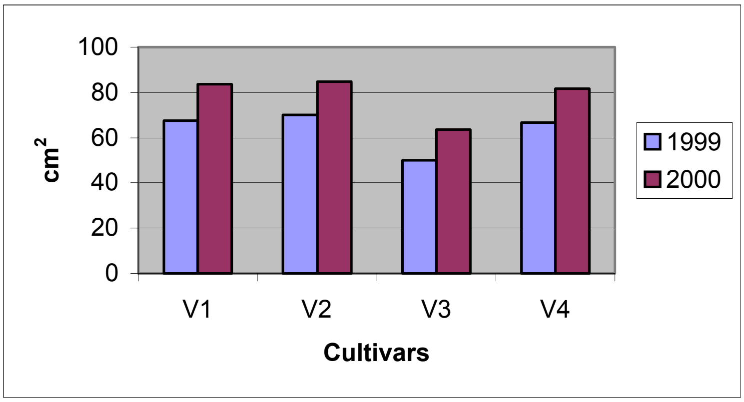
Leaf Area cm^2:



Loc1: Soba Treatment Plant Premises *Loc2: Soba Demonstration Farm*

N: Normal Water *S: Treated Sewage Water*

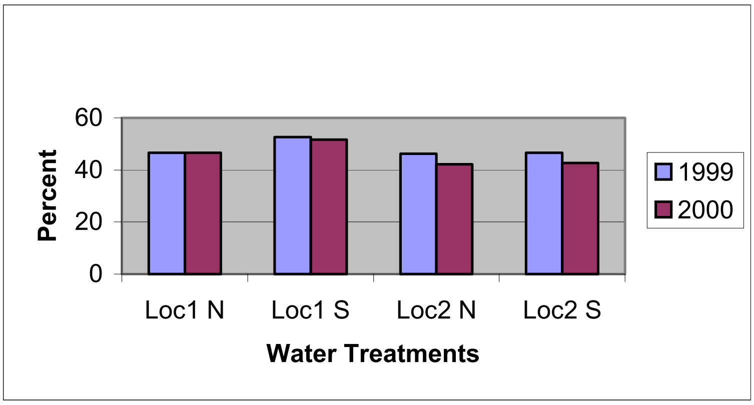
Figure 4a: Effect of Water Quality at different growth stages on leaf area during seasons 1999- 2000



V1: Sorghum bicolor "Abu 70", V2: Pioneer, V3: Speed feed & V4: Panar

Figure 4b: Effect of cultivars on Leave Area during seasons 1999/2000

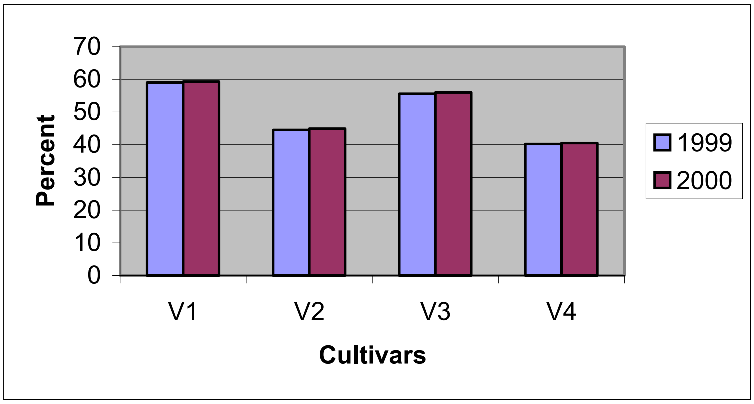
Leaf / Stem Ratio



Loc1: Soba Treatment Plant Premises *Loc2: Soba Demonstration Farm*

N: Normal Water *S: Treated Sewage Water*

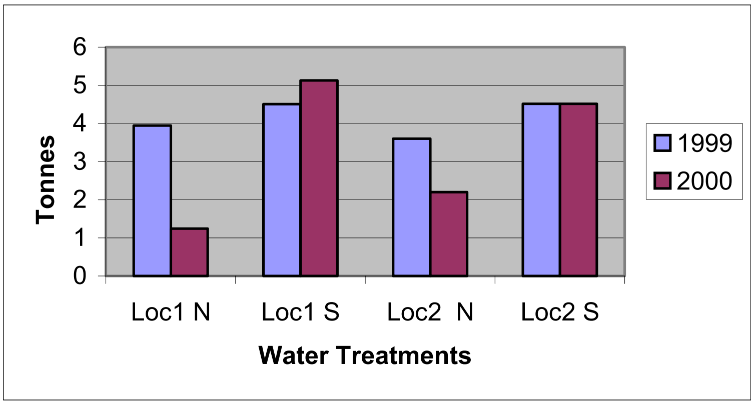
Figure 5a: Effect of water quality at different growth stages on leaf/stem ratio during seasons 1999/ 2000



V1: Sorghum bicolor "Abu 70", V2: Pioneer, V3: Speed feed & V4: Panar

Figure 5b: Effect of cultivars on leave/stem ratio during seasons 1999/ 2000

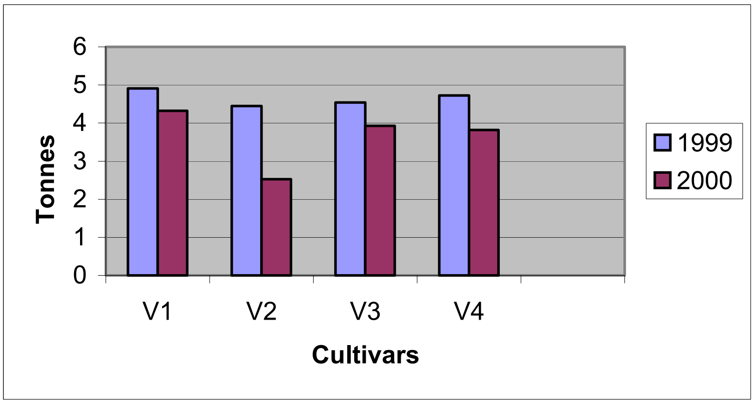
Yield tones/ha



Loc1: Soba Treatment Plant Premises *Loc2: Soba Demonstration Farm*

N: Normal Water *S: Treated Sewage Water*

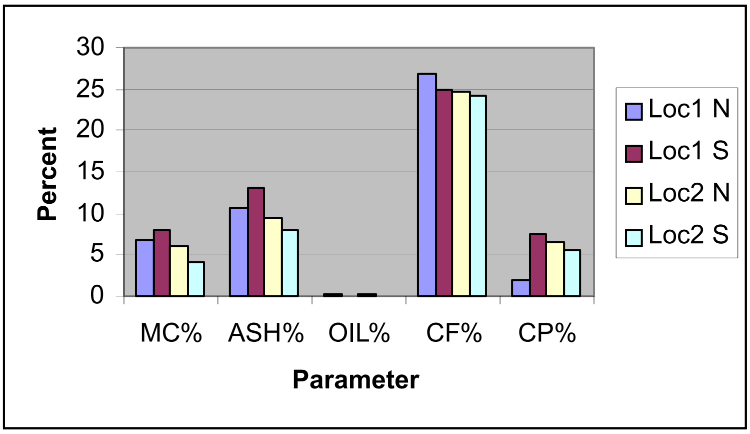
Figure 6: Effect of Water Quality on Dry Yield (ton/ha) during seasons 1999/ 2000



V1: Sorghum bicolor "Abu 70", V2: Pioneer, V3: Speed feed & V4: Panar

Figure 7: Effect of cultivars on Yield (ton/ha) dry weight during both seasons 1999/ 2000

Proximate composition analysis:



Loc1: Soba Treatment Plant Premises *Loc2: Soba Demonstration Farm*

N: Normal Water *S: Treated Sewage Water*

Figure 8: Proximate composition analysis for the forage samples

MC: Moisture Content

CP: Crude Protein

CF: Crude Fiber

Chemical constituents of crop tissues were summarized as averages of both seasons and presented in Table (3)

Table 3: Averages of chemical constituents of the crop tissues (averages for both seasons 1999 & 2000).

	Loc 1		Loc 2	
	N	S	N	S
Na mg/l	22.16	24.66	22.02	24.87
K	13.95	16.91	13.5	16.65
Cu	0.12	0.123	0.21	0.195
Fe	61.22	63.3	73.8	74.87
Zn	0.443	0.47	0.463	0.41
Mn	1.269	0.775	1.3	1.0
Co	0.087	0.092	0.08	0.07

4. Discussion and Conclusions

Some consulting engineers and public health authorities came to believe that sewage farming was undesirable and unsanitary for some crops to the extent that some countries prohibited cultivating consumable crops with Treated Sewage Water. Eventually the trend was diverted towards producing forages and forest trees by treated sewage water. The benefits were multiple, since in producing forages by sewage water expensive fertilizers and potable water can be saved; nutrients are retained to land and in the same time low cost forages can be produced. By growing trees microclimate is improved, firewood and timber are sustained and revenues are achieved.

The idea of the present study arises from the previously mentioned objectives to the extent that it evaluates fodder production in two locations of the same type for two consecutive seasons. One has to make sure that producing forages in a land previously received treated sewage water for almost thirty years could have any effects to plants and if it happened that this water is administered into a virgin land does that has any effects too.

It was evident from the present study that the effect of treated sewage water on plant performance and growth showed significant differences. It resulted in relatively taller plants compared to those irrigated with normal water through out the different sampling intervals. The forage plants of all cultivars looked vigorous and healthy when irrigated with treated sewage water compared to those irrigated with normal water. This healthy appearance might be an indication that the wastewater had acted as a fertilizer.

These findings are in agreement with those reported by Halsey (1960) and Romison (1980), which stated that, the requirement of sorghum for nitrogen is a pre-requisite for quick growth. Our results came out with relatively higher concentration of Nitrogen and essential plant nutrients and no phytotoxicity symptoms were observed on the crops grown and irrigated with wastewater. The four forage cultivars were normal in their performance during germination, establishment and survival.

Treated sewage water significantly increased the yield (fresh and dry matter) of the four forages. The soil affected by treated sewage water for many years gave higher yield than the virgin soil that received the same water. Crude protein concentration in the crops of location 1 were highest in both seasons, it ranged from 4.24 to 9.9 % in the first season where as in the second season ranged from 6.2 to 11.6 and V_2 (Pioneer) had the highest values in both seasons. Elamin (1990) recorded that for grass forage the crude protein range was 9 – 14 %, which is within the normal range of grasses. There was no clear variation in crude fiber content between the four forages due to watering or cultivars but average fiber content of the crops irrigated with treated sewage water came in line with Elamin (1990) who mentioned that crude fiber for grasses might reach 32 %. In comparison to these values; it is worth mentioning that the crude fiber content of the tested forages grown under such conditions of soils and water gave crude fiber content between 20-30%.

The forages produced with wastewater can be used for feeding livestock and it can supply the domestic animals with their nutrient requirements. Sherwood (1974) recommended the following crude protein allowances for the different classes of animals: poultry 15-20 %, sheep 10-16 %, dairy cattle 7.5-12 % and beef 18%. Using treated sewage water in irrigation will minimize the volume of wastewater by introducing the water into the fields and save the environment and fulfill efficient utilization of resources. But careful precautions could be adopted with regard to cultivation practices

Crops are not at all recommended receiving large quantities of water, the plants should receive what they actually need because these waste water form slime and algae on the land which might suffocates plants and decrease downward movement of water to the roots.

Crops should be planted on ridges rather than flat beds, in so doing, plants will be away from the direct contact with water. Also the crops should be seeded on the shoulders of the ridges as flat beds could contribute to death of plants by water logging.

Farmers should be aware of the hazards of working in this wastewater, they should wear high boots to protect their feet and should avoid direct contact with water like washing their hands or cleaning their clothes or else. They should wash and clean themselves when they come out of the fields.

From agronomic point of view, sewage effluent can substitute for high quality groundwater use in agriculture or in times of no irrigation requirement can be reused for recharge to ground water.

REFERENCES

A. O. A. C. (1984). Official methods of analysis of the Association of Official Analytical Chemists. Fourteenth ed. Published by the A. O. O. C. Inc. Virginia 22209, USA.

Elamin, N. A. (1990). Utilization of industrial Waste Water in Forage Production. M.Sc. Thesis Agriculture, University of Khartoum.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research, 2nd Ed. John Willey and Sons. Inc. New York

Hasley, L. H. (1960). Influence of Nitrogen Fertilizer and Seed Inoculation level on yield of Southern Pea. Jer. Of American Soc. Hort. Society, 75: 517-520.

National Forestry Corporation, 1997. Personal contact with the Green Belt Manager.

Pearson, D. I. (1976). The Chemical Analysis of Foods, 7th edition, Churchil Livigstone, Edinburgh, London, New York.

Romison, S. V. (1980). Mineral nutition of Cow Pea. Vigna unguiculata (L) (Walp) Abst. Trop. Agric. 7: 38-345

Shrewood, F. W. (1947). Effect of Fertilization on Nitrogen, calcium and Phoshorous Content of Pasture herbage. J Amer. Soc. Agron. 39:58-84

Sudan Republic Gazette, 1962. No. 978 dated 15 December 1962 Sudan Republic.

Watson, D. J., and Watson, M. A. (1953). Comparative Physiological Studies on the Growth of Field Crops. Ann. Appl. Biol.. 40: 1;6

Whitehouse, K. Zorow, A. and Shay, H. (1945). Rapid Method for Determining Crude Fibre in Distillators dried grain. J. of the Association of official Agricultural chemists. 28 (1), 147-152.