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REGULAR ARTICLE

YIELD AND WATER USE EFFICIENCY OF BARLEY FODDER PRODUCED UNDER HYDROPONIC SYSTEM IN GCC COUNTRIES USING TERTIARY TREATED SEWAGE EFFLUENTS

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SUMMARY

In the Gulf Cooperation Council (GCC) Countries, where water is a major limitation in crop production, using alternative water resources such as tertiary treated sewage effluent (TTSE) is one way to produce crops, especially fodders which consume sizeable share of the limited irrigation water. Barley (*Hordium vulgare* L.) is a popular fodder in the region with good adaptability to wide range of climate and soil. A laboratory experiment was conducted during 2009 using complete randomized design with four replications in order to evaluate yield, water use efficiency (WUE) and quality of barley fodder irrigated with TTSE under hydroponic system. Barley seeds of a commercial grade with good viability (80-85%) were sterilized with 20% sodium hypochlorite solution to control fungal growth. Seeds were sown in stacked trays in a temperature controlled room. Trays were irrigated daily with either tap water (T1), or tap water mixed with TTSE at 20%, 40%, 60%, 80% (T2 to T5) and with TTSE only (T6). Plants were harvested 9 days after sowing. Plant height, green and dry fodder weight, the germination percentages and the amount of water used were recorded. Representative fresh green fodder samples from each treatment were oven-dried at 70^{o}C for 48 hrs and analyzed. Crude protein, Crude fiber CF, acid detergent fiber (ADF), neutral detergent fiber (NDF) and lipid concentrations were determined. Results indicated that germination percent and yield of barley increased as the concentration of TTSE in irrigation water increased, however, the increase in WUE was not significant. Proximate chemical analyses indicated that there was no significant effect of treated sewage effluent on moisture, CF, NDF, ADF, or fat (ether extract) of the barley fodder. It was concluded that barley produced by TTSE maintained all its fodder quality and that it can be produced commercially for feeding livestock.

Keywords: Treated sewage effluent, fodder barley, hydroponic systems, water use efficiency.

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1. Introduction

The Gulf Cooperation Council (GCC) countries are located in a desert region, which is characterized by high temperatures, high evaporation rates and low and erratic rainfall. Irrigated agriculture is by far the largest water user with around 78% on average of the total water use in all GCC countries [1]. Most agricultural water (85%) is groundwater, which is largely non-renewable [2]. The amount of abstraction of ground water is by far greater than the recharge and aquifer levels are rapidly declining and ground water is increasing in salinity by intrusion of sea water [1]. There is a sharp decline in availability of underground water to be used for irrigation in the GCC region. Water use efficiency (WUE) is generally low under field conditions in the region [3]. Several strategies have been suggested to improve the productivity of water, among which is better management of the water resource [4]. Hydroponics growing techniques improve WUE by restricting water loss [5]. This technique can be used to produce fodder in very short periods (7-10 days) and it has been proven to be efficient both financially and environmentally [6]. It is estimated that with this technique, the costs of agricultural inputs are at least 10 times lower than under field conditions [7]. High water use efficiency is, however, a major advantage of this technique which saves about 95-97% of used water in comparison to conventional agriculture with small piece of land [3].

Green forage production in the GCC countries is limited by its high water consumption and less water use efficiency per unit of green forage produced (130 liters per kg green fodder) [8]. The limited availability of traditional water resources necessitates the use of non-traditional resources in agriculture among which is treated sewage water. The current primary use of treated wastewater in GCC countries is for municipal landscaping while a significant volume is lost to the sea even after it is treated to the secondary level [1]. Currently, about 60% of sewage effluent in GCC countries is treated but its use in agriculture accounts for only 2% of the total amount of water used in crop production [1].

The present study aimed at studying the potential of utilizing tertiary treated sewage effluent (TTSE) to produce fresh and safe barley fodder using hydroponics system. This work is presented in two papers. The current paper investigates yield and WUE of the hydroponically produced barley sprouts using TTSE. Issues related to chemical compositions and heavy metals residues in plant tissues are covered in the subsequent paper.

2. Materials and methods

The experiment was conducted in a temperature controlled room (23±2O C, RH 70 ±5%) at Sultan Qaboos Center for Developed and Soilless Agriculture, Arabian Gulf University, Bahrain, in a hydroponic system. Clean seeds of barley (*Hordeum vulgare* L.) of a commercial grade with good viability (80-85%) were used. Seeds were sterilized by soaking for 30 minutes in 20% sodium hypochlorite solution. Seeds were then washed and soaked in distilled water for 14 hours. Eighty grams of seeds were sown per tray (dimensions 40 cm × 43 cm × 6 cm). This is equivalent to seed rate of 4.65 kg/m^2. Holes were made at the bottom of the plastic trays to freely drain excess irrigation water. The trays were stacked on shelves in a randomized complete block design with four replicates. The trays were covered with plastic cover to prevent seed drying.

Trays were irrigated daily with either tap water (T1, control), or tap water mixed with tertiary treated sewage effluent (TTSE) at 20%, 40%, 60%, 80% (T2 to T5) and with TTSE only (T6).

The experiment was terminated 9 days after sowing by harvesting the plants. The data collected included plant height, green and dry fodder weight, the amount of non-germinated seeds and the amount of water used. Water use efficiency was computed as amount of dry matter produced/unit of water used.

The proximate chemical composition of dry fodder samples was determined according to standard methods of AOAC (2000). Dry matter (DM) was determined by drying in an oven for 24 hours at 80ºC (method 934.01). Crude protein (CP) was determined using a Foss Tecator Kjeltec 2300 Nitrogen / Protein Analyzer (method 976.05). Fat (ether extract EE) was determined by Soxhlet extraction of the dry sample, using petroleum ether (method 920.39). Ash content was determined by ashing samples in a muffle furnace at 500ºC for 24 hr (method 942.05). Acid detergent fibre (ADF) was determined using cetyl trimethyl ammonium bromide (CTAB) and 1N H2SO4 [9]. Neutral detergent fiber (NDF) was determined using sodium sulphite and sodium lauryl sulphates [10]. Crude fiber was analyzed by FOSS Fibertec system according to Weende, van Soest method.

Data were statistically analyzed using analyses of variance (ANOVA) by MSTAT Statistical Package [11]. Probabilities of significance among treatments and interaction and LSDs ($P<0.05$) were used to compare means within and among treatments.

3. Results and discussion

Irrigation water quality

The analysis of irrigation water used for the various treatments is reported in Table 1. The salinity of irrigation water ranged between 0.34 dS/m (tap water) and 4.08 dS/m (TTSE). The pH values ranged from 7.28 for the tap water to 7.94 for the TTSE. Nitrogen content increased from 100 ppm in tap water (control, T1) to 290 ppm in pure TTSE (T6). As expected, the levels of EC, pH and total nitrogen in various treatments (T2-T5) have progressively increased with increasing the proportion of TTSE in the irrigation water (Tables 1).

Table 1. EC, pH and nitrogen content of irrigation water used in the various treatments.

Treatments	TTSE in irrigation water (%)	EC (dS/m)	pH	Total N (ppm)
T1	Tap water only	0.34	7.28	10
T2	20	1.1	7.33	80
T3	40	1.9	7.37	160
T4	60	3.07	7.42	180
T5	80	3.48	7.72	220
T6	TTSE only	4.08	7.94	290

It has been reported that hydroponically grown barley can tolerate EC values above 6 dS/m without any impact on seed germination or crop yield [12]. N concentration in TTSE is adequate to maintain good barley growth according to Benton [13].

Fodder yield

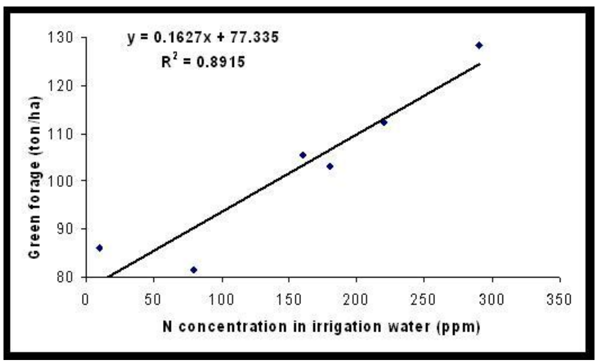
Table 2 shows total crop yields (on green and dry weight basis) and crop heights at harvest. Average green forage yield ranged from less than 90 tones/ha with tap water to around 130 tones/ha with TTSE (T6). This is equivalent to 50% increase in fodder production. This increase in yield may be attributed to the high nitrogen content in TTSE.

Table 2; Fresh yield, dry matter, plant height and ratio of green forage to seeds rate of barley in the various treatments.

Treatments	Green forage ton/ha	Dry matter ton/ha	Crop heights at harvest (cm)	Green forage to seeds rate
T1	86.1[c]	19.46[a]	15.3[a]	1.85[c]
T2	81.6[c]	16.32[ab]	15.1[a]	1.75[c]
T3	105.6[abc]	21.65[abc]	16.0[a]	2.27[abc]
T4	103.0[bc]	20.91[bc]	14.9[a]	2.22[bc]
T5	112.3[ab]	23.02[c]	17.1[a]	2.42[ab]
T6	128.3[a]	24.63[c]	18.1[a]	2.76[a]

Means followed by the same letter in a column are not significantly different at P<0.05.

Fig. 1. Green forage production of barley crop as affected by nitrogen content in irrigation water.



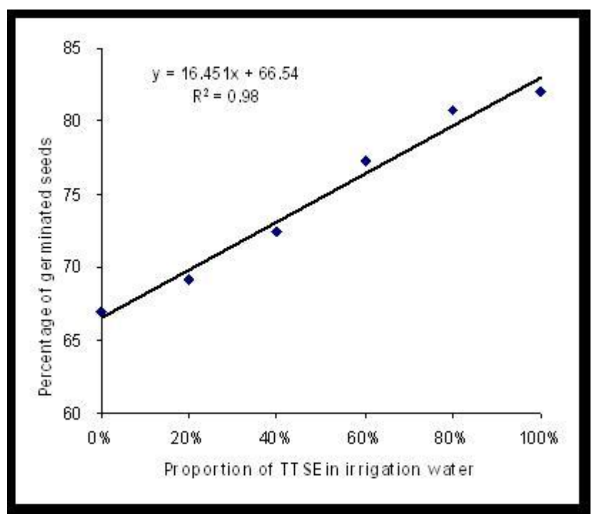
Green forage production is highly correlated to N content of irrigation water with a correlation coefficient R2 =0.89 (Figure 1). Márcia Rejane et al. [14] used treated waste water supplemented with different levels of nitrogen for production of hybrid fodder corn in Brazil. They found that irrigation with treated sewage water increased fodder production by 144% over production using provisional water and that there was a linear increase in fodder yield with increasing nitrogen doze. In terms of dry matter (DM) production, seeds irrigated with TTSE produced 25% more hay than tap water (Table 2).

With a fixed seeding rate of 4.65 Kg/m2 (46.5 ton/ha) used in this experiment, the average ratio of green forage obtained to seeds rate (GF:SR) significantly increased with increasing TTSE proportion in irrigation water to a maximum of 2.76 with TTSE (Table 2). Al Hashmi [16] obtained a slightly higher GF:SR ratio of about 3 with tap water.

Seed Germination

There has been a significant increase in the rate of germination of the sprouted seeds with the increase in TTSE proportion in irrigation water with a correlation coefficient that approaches 1 (Figure 2). High N content in TTSE might have induced higher germination rate of barley seeds and consequently, more forage yield. This finding is of a great importance because it saves on the cost of seeds needed for sprouting and hence increases the efficiency of seed productivity. It also improves the healthiness of produced fodder by reducing mould incidence [17].

Fig. 2. Percentage of germinated seeds as affected by TTSE proportion in irrigation water.



Bole and Gould [18] found that Reed canary grass (*Phalaris arundinacea* L.) yields were doubled by the application of 10 cm /year of wastewater compared with irrigation water and with water supplemented with either nitrogen or phosphorus fertilizers or carbon as sugar at rates similar to those found in wastewater. Peer and Lesson [19] cited low germination of barley kernels as a major problem in hydroponically produced barley fodder.

Fodder quality

Table 3 shows that there was no significant effect of treated sewage effluent on fodder quality in terms of moisture content, crude protein (CP), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), or fat (ether extract EE). This study indicated that barely irrigated with various levels of treated sewage effluent may be used for feeding livestock without adverse effects on health or performance. It offers good use of treated sewage effluent to increase farmer's benefits. Proximate chemical analyses indicated that barely fodder may probably be superior in some aspects to commercial Rhodes grass hay used mainly as a source of roughage for livestock in the Gulf region. Taha et al. [20] reported that irrigation with TSE resulted in relatively taller sorghum plants; plants looked vigorous and healthy, with less fiber content, high protein values and significantly higher dry yields compared to those irrigated by normal water.

Table 3 Proximate analyses of barley irrigated with various levels of treated sewage effluent (TTSE). MSE: Mean standard error

Parameters %	Treatments						MSE	Significance
	T1	T2	T3	T4	T5	T6		
Moisture content	8.39	8.15	7.95	7.75	7.97	8.08	0.467	NS
Crude protein (CP)	14.00	13.71	13.79	14.00	13.85	16.08	2.46	NS
Acid detergent fiber (ADF)	13.33	15.49	15.35	14.98	14.83	15.12	2.839	NS
Neutral detergent fiber (NDF)	30.43	32.77	33.73	33.48	33.11	33.21	6.485	NS
Crude fiber (CF)	11.20	12.18	11.76	10.90	11.64	11.50	3.789	NS
fat (ether extract EE)	3.61	3.67	3.60	3.03	3.49	3.28	0.345	NS

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Water use efficiency

Barley plants utilized 30% more water when irrigated with TTSE than with tap water, while dry matter production with TTSE was higher by over 20% (Table 4). As mentioned earlier, the maximum dry matter production realized was around 25 tons/ha using TTSE compared to less than 20 tons/ha with tap water (table 2). This improvement in crop yields might be appreciable and economically feasible. Statistical analyses, however, revealed no significant differences among treatments in terms of water use efficiency (dry matter produced per unit water used). When comparison is made with barley crop grown under field conditions, Hussain and Al-Jaloud [21] achieved a WUE of only 0.22 Kg DM/m3 water for well-watered field irrigated barley in Saudi Arabia compared to above 2 tones DM/m3 water in this study. This is a tremendous improvement in WUE and indicated that hydroponic system could play a significant role in improving water use efficiency in GCC countries.

Table 4: Water use and water use efficiency of barley irrigated with different levels of TTSE.

Treatments	Water used m^3/ha	WUE (Ton DM/m^3 water used)
T1	8.23	2.36
T2	9.62	1.70
T3	10.78	2.01
T4	9.94	2.10
T5	11.42	2.02
T6	11.74	2.10

Conclusions

Hydroponic system is a potential technique for barley production with least water consumption in GCC countries where water is the main limiting factor for agricultural production. Tertiary treated sewage effluent is a feasible source for irrigation of hydroponically produced barley crop. The current study shows the superiority of TTSE irrigated fodder barley over that irrigated with tap water in several aspects related to production and quality of the produced barley crop.

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References

[1] World Bank, 2005. Water Sector Assessment Report on the Country of the cooperation of the Gulf, Report No. 32539 – MNA, 83 pp.

[2] Bazza, M., 2005. Policies for Water Management and Food Security under Water-scarcity Conditions: The Case of GCC Countries. 7th Gulf Water Conference Kuwait. 15 p.

[3] Al Hashmi, M., 2006. Green forage production in Arabian Gulf countries: current situation and alternative techniques. A scientific report submitted in partial fulfillment of requirement for high diploma in desert and soilless agriculture. Desert and arid zones programme. Arabian Gulf University. Bahrain. 39 p.

[4] Wang, H.X., Liu, C.M., Zhang, L., 2002. Water-saving agriculture in China: an overview. Advances in Agronomy 75, 135–171.

[5] Jensen, H., Malter, A., 1995. Protected agriculture, a global review. World Bank technical paper number 253. 156 p.

[6] Rotar, P., 2004. Hydroponic techniques sprout healthy, inexpensive Fodder. Accessed through [http://www.isar.org/pubs/ST/hydroponics47.html].

[7] Mooney, J., 2005. Growing cattle feed hydroponically. Meat and livestock Australia. 30 p.

[8] Al Derazi, K.E., 2003. Green fodder production in Bahrain water cost and the alternative approach. A master thesis submitted in partial fulfillment of master degree requirement. Desert and arid zones sciences program. Arabian Gulf University. Bahrain. 100 p. (in Arabic).

[9] Robertson, J.B., Van Soest, P.J., 1981. The detergent system of analysis. In: James, W.P.T., Theander, O. (Eds.). The Analysis of Dietary Fiber in Food. Marcel Dekker, NY, Chapter 9, pp. 123–158.

[10] Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583-3597.

[11] SAS Institute, 1996: The SAS System for Windows. Release 10.0. SAS Institute, Cary, NC.

[12] Bagci, S.A., Yilmaz, H.E.A., 2003. Determination of the salt tolerance of some barley genotypes and the characteristics affecting tolerance. Turk. J. Agric. For. 27 , 253-260.

[13] Benton, J. 2005. Hydroponics; A practical Guide for the Soilless grower. 2nd Ed. CRC press, USA.

[14] Márcia Rejane de Queiroz Almeida Azevedo, Annemarie König, Napoleão Esberard de Macêdo Beltrão, Beatriz Suzana Ovrusky de Ceballos, Carlos Alberto Vieira de Azevedo, Tatiana de Lima Tavares. (2006) Effects of the Irrigation with Treated Wastewater on Fodder Corn Production, Paper number 062094 ASAE Annual Meeting.

[15] Snow, A.M., Ghaly A.E., 2008. Use of barley for the purification of aquaculture wastewater in a hydroponics system. American J. Environ. Sci. 4 (2), 89-102.

[16] Al Hashmi, M., 2008. Hydroponic green fodder production in the Arabian Gulf region. M.Sc. Thesis, Desert and arid zones programme, Arabian Gulf University, Bahrain.

[17] Sneath, R. McIntosh, F., 2003. Review of hydroponic fodder production for beef cattle. Australian Queensland government, department of primary industries. 55p.

[18] Bole, J.B., Gould, W.D., 1985. Irrigation of forages with rendering plant wastewater:

forage yield and nitrogen dynamics. J. Environ. Qual. 14, 119-126.

[19] Peer, D.J., Leeson, S., 1985. Feeding value of hydroponically sprouted barley for poultry and pigs. Anim. Feed Sci. Techno. 13, 183-190.

[20] Taha, I.M., Hamza, N.B., Malik, M.N., 2002. Utilization of treated sewage water for forage production. Proceedings of international symposium on environmental pollution control and waste management. 7-10 January 2002, Tunis (EPCOWM'2002), p.560-572.

[21] Hussain, G., Al-Jaloud A.A., 1998. Effect of irrigation and nitrogen on yield, yield components and water use efficiency of barley in Saudi Arabia. Ag. Wat. Manage. 36, 55-70.