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RESPONSE OF SORGHUM (*Sorghum bicolor* M.) TO THREE IRRIGATION SYSTEMS UNDER TREATED WASTE WATER AND FRESH WATER IRRIGATIONS SYSTEM

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KEYWORDS

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Freshwater

Irrigation

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ABSTRACT

The treated wastewater is highly used as an alternate source of water for growing crops like sorghum for forage/fodder to livestock in Arabian Peninsula water deficit countries including Oman. In present study, high forage yielding sorghum variety, Superdan was investigated under three irrigation systems (Surface, Sub-surface and Drips) at Agriculture Research Station, Rumais, Oman, for its response to treated wastewater and fresh water irrigation conditions with respect to forage productivity. Study was conducted over continuous 11 forage harvests which started from summer season (April, 2013) and completed in mid-winter season (March, 2015). The results of study revealed that both mean green and dry matter yields/ cut and their total yield over 680 days were significantly higher under drip irrigation and it was followed by sub-surface and surface irrigation systems in both treated and freshwater irrigations. Water use efficiency (WUE) of sorghum was significantly higher under drip irrigation than under other irrigation systems not only with treated wastewater (2.54) but also with freshwater irrigation (2.49). The concentrations of heavy elements were either very low, low or in trace amount under the limits of toxicity threshold in both plant samples and soil samples. The present study demonstrated that forage sorghum can last till 11 cut-harvests spanning 680 days providing total green and dry matter yields of 508.30 t/ha and 143.88 t/ha respectively under treated wastewater irrigation compared to total green and dry matter yields of 498.26 t/ha and 144.58 t/ha, respectively under freshwater irrigation.

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1 Introduction

The treated wastewater is nowadays used for growing crops for forage or fodder to livestock and helps in decreasing the pressure of normal water use in the countries of the Arabian Peninsula including Oman that face water scarcity. However, its application requires effective treatment to safeguard public health and environment at economic cost (Anderson et al., 2001; Agunwamba, 2001; Sipala et al., 2003; Ling et al., 2011; Khan et al., 2012).

The problem of fresh water scarcity exists in all the arid and semi-arid areas of the world. The problem assumes grave in the countries, which are largely dependent on agriculture. Application of treated wastewater for irrigation in many countries has been considered in practice as an alternative to available water to irrigate crops to address the problem of water scarcity (Al-Rashed & Sherif, 2000; Aghtape et al., 2011; Khan et al., 2012).

Sorghum (*Sorghum bicolor* Moench.) is the most important drought tolerant forage crop in summer season in semi-arid tropic regions of the world like Oman (Akhtar & Nadaf, 2002). In most of the countries, sorghum is mainly used as green fodder. However, in India and Africa it is grown as a cereal grain food crop (Khan et al., 2010). It has the ability to tolerate water stress and survive even under sub-marginal conditions (Duarte et al., 2000; Khan et al., 2010).

The treated wastewater is found to provide a good source of N, P and K for better growth of fodder crops like sorghum, pearl millet, maize, etc. under treated wastewater (Khan et al., 2010; Al-Khamisi et al., 2011). However, very few studies investigated for appropriate irrigation system under arid conditions especially for cultivation of sorghum forage. Among these, Adams & Stevenson (1990), El-Aref et al. (2005) and Sakellariou-Makrantonaki et al. (2007) found drip irrigation system to be efficient for crop growth as it delivers continuous and adequate water supply into plant root zone among other irrigation systems studied.

In view of the above, the present study was undertaken to explore the potential of three irrigation systems using treated wastewater available from STPs (Sewage Treatment Plant) in the country for the growth of forage sorghum variety, Superdan in producing higher yield of fodder in comparison with that by use of fresh available water with no deleterious elements in fodder.

2 Materials and Methods

The present experiment was undertaken from April 2013 to March 2015 under split-plot arrangement in RCBD. In this experiment water type was main factor viz. Fresh water and Treated wastewater and irrigation system was the sub factor viz. surface, sub-surface and drip irrigation. Seeds of forage sorghum variety from Australia namely Superdan were planted in plots consisting of four 3m rows at 25 cm between rows in plots of 3m x 4m and 15 cm between plants in each irrigation system under each water type during April, 2013. The first harvest of crop was taken-up for fodder during first week of July, 2013 when the crop showed 25-50% flowering. The crop was subsequently harvested for green forage ten times till the last cut-harvest made during March 2015. The experimental period lasted almost 680 days. Plots were irrigated half hour three times every week and fertilized with 100:50:50 kg NPK/ha as per national recommendations (Akhtar & Nadaf, 2002). At each fodder harvest, plant height (cm) and green matter weight (kg/m^2) were recorded. The water applied up to each harvest was recorded from water meters fixed for each irrigation system. The fresh random samples of harvest were taken for each genotype for the determination of dry matter content (AOAC, 1984). The water-use efficiency (WUE) was computed using the value of quantity water applied for every cut-harvest. SPAD values of leaf samples were also measured during each harvest period using SPAD-502 meter. These values are proportional to the amount of chlorophyll present in the leaf chlorophyll content (Ling et al., 2011). The experimental data were subjected to analysis of variance according to Gomez and Gomez using M-Stat-C software.

3 Results and Discussion

Results presented in tables 1 to 5 revealed means plant height (cm), chlorophyll (SPAD values), green and dry matter yield (t/ha), and water-use efficiency (WUE) over 11 cut-harvests of forage sorghum hybrid, Superdan used for investigation.

3.1 Plant height

With respect the plant height, effects of water type, irrigation system and cut-harvests were found significant ($p<0.05$) while all the interaction were found not significant ($p>0.05$) (Table 1). The plant height under treated wastewater was significantly higher (164.66 cm) than the freshwater. Similar improvement in plant height under treated wastewater conditions was also previously reported in pearl millet (Khan et al., 2012), maize, sorghum and other cereal fodder crops (Agunwamba, 2001; Khan et al., 2010; Al-Khamisi et al., 2011). Vegetative characters like plant height are influenced by NPK and organic matter, which are abundantly found in treated wastewater in improving the plant growth. In present experiment also higher concentration N and K were found in treated wastewater (N – 28.7 mg/l and K- 22.93 mg/l) than the fresh water irrigation ((N – 0.463 mg/l and K- 17.83 mg/l) (Table 8). In the samples of both the water types, P was found undetected. Among the irrigation systems, sorghum responded significantly superior in terms of plant height under drip irrigation than under other irrigation systems (Table 1) not only with treated

Table 1 Means of plant height (cm) in sorghum under treated wastewater and freshwater in three irrigation systems

Cuts	Treated wastewater				Fresh water			
	Drip	Surface	Sub surface	Mean	Drip	Surface	Sub surface	Mean
Cut-1	242.00	230.50	207.50	226.67	205.00	229.75	194.50	209.75
Cut-2	174.75	165.25	162.25	167.42	165.25	149.50	160.75	158.50
Cut-3	196.25	192.25	158.75	182.42	202.50	173.25	188.25	188.00
Cut-4	172.75	174.00	168.75	171.83	173.00	168.00	179.75	173.58
Cut-5	144.30	131.75	135.70	137.25	131.20	137.80	123.40	130.80
Cut-6	144.00	145.00	126.75	138.58	141.50	150.00	138.75	143.42
Cut-7	105.00	106.00	109.25	106.75	97.00	89.00	82.75	89.58
Cut-8	184.50	173.75	165.50	174.58	157.25	160.50	141.25	153.00
Cut-9	208.50	194.25	196.00	199.58	193.00	195.50	177.25	188.58
Cut-10	169.00	171.25	167.75	169.33	164.00	166.25	158.50	162.92
Cut-11	154.25	137.00	119.25	136.83	142.75	141.75	135.25	139.92
Mean	172.30	165.55	156.13	164.66	161.13	160.12	152.76	158.00

Statistical parameters	F-test	LSD (5%)
Water type	**	4.85
Irrigation system	**	5.83
Cuts	**	11.36
Water type × Irrigation system	NS	-
Water type × Cuts	NS	-
Irrigation system × Cuts	NS	-
Water type × Irrigation system × Cuts	NS	-
C. V. (%)		12.4

wastewater (172.30 cm) but also with freshwater irrigation. This was also observed in sorghum by El-Aref et al. (2015).

3.2 *Leaf Chlorophyll Content*

It is well known that leaf color shows the amount and proportion of chlorophyll in leaves that make plant nutrient status. Hence, leaf colour, as a function of chlorophyll content, could be used as an index to diagnose nutrient status. In the present study, SPAD values recorded for chlorophyll were used to indicate plant nutrient status for interpretation of results. In respect of chlorophyll, only the main effect of cut-harvests and interaction effect of water type and cut-harvest were found significant ($p<0.05$) while all the other effects were not significant ($p>0.05$) (Table 2). There were no significant differences in SPAD values ($p>0.05$) obtained in the plant samples under use of either treated wastewater or freshwater in all the irrigation systems. However, these values were significantly different between the samples taken in the periods of different cut-harvests which is attributed to differential conditions of growth prevailed during different cut-harvests.

3.3 *Green and dry matter yields (t/ha)*

With respect of green matter yield, only the main effects of irrigation system and cut-harvests were highly significant ($p<0.05$) whereas the interaction effects of water type x irrigation system and that of irrigation system x cuts were found significant ($p<0.05$). However, other interaction effects were not found significant ($p>0.05$) (Table 3). In respect of dry matter yield all the effects were significant ($p<0.05$) to highly significant ($p<0.01$) except the main effect of water type and that of three-factor interaction, which were non-significant ($p>0.05$). Both green and dry matter yields were significantly superior under drip irrigation system than under sub-surface and surface irrigation systems not only in terms of mean yields but also total yield over cuts for the experimental period (680 days) in both treated and freshwater irrigations (Tables 3 and 4). The over-all mean and total green matter yield of 48.74 t/ha and 584.90 t/ha were obtained under drip irrigation system as compared to 42.76 t/ha and 513.14 t/ha under surface irrigation and 35.57 t/ha and 426.87 t/ha under sub-surface irrigation systems with the use of treated wastewater. However, in case of freshwater irrigation, the over-all mean and total green matter

Table 2 Means of chlorophyll (SPAD values) in sorghum under treated wastewater and fresh water in three irrigation systems

Cuts	Treated wastewater				Fresh water			
	Drip	Surface	Sub surface	Mean	Drip	Surface	Sub surface	Mean
Cut-1	45.00	46.00	44.75	45.25	45.25	42.50	38.75	42.17
Cut-2	38.00	34.75	30.75	34.50	41.75	36.00	42.00	39.92
Cut-3	43.05	40.43	38.33	40.60	42.98	42.63	39.78	41.79
Cut-4	48.50	45.75	39.00	44.42	40.50	41.00	37.75	39.75
Cut-5	34.63	36.40	37.80	36.28	29.63	34.15	33.48	32.42
Cut-6	38.80	43.23	42.08	41.37	38.10	39.63	39.08	38.93
Cut-7	36.25	36.25	41.25	37.92	46.25	42.25	43.25	43.92
Cut-8	40.03	40.95	40.83	40.60	43.58	43.23	42.53	43.11
Cut-9	43.85	42.93	40.80	42.53	44.68	43.58	41.20	43.15
Cut-10	40.00	42.00	41.75	41.25	42.00	41.50	41.50	41.67
Cut-11	43.00	41.75	39.75	41.50	40.00	41.50	40.50	40.67
Mean	41.01	40.95	39.73	40.56	41.34	40.72	39.98	40.68

Statistical parameters	F-test	LSD (5%)
Water type	NS	-
Irrigation system	NS	-
Cuts	**	3.12
Water type × Irrigation system	NS	-
Water type × Cuts	**	4.41
Irrigation system × Cuts	NS	-
Water type × Irrigation system × Cuts	NS	-
C. V. (%)		13.5

Table 3 Means of green matter yield (t/ha) in sorghum under treated wastewater and freshwater in three irrigation systems

Cuts	Treated wastewater				Fresh water			
	Drip	Surface	Sub surface	Mean	Drip	Surface	Sub surface	Mean
Cut-1	84.52	64.12	39.01	62.55	78.23	80.93	47.52	68.89
Cut-2	63.50	59.14	47.31	56.65	61.01	53.74	49.59	54.78
Cut-3	86.88	73.08	59.88	73.28	83.40	73.93	79.20	78.84
Cut-4	47.65	52.10	45.05	48.27	44.83	36.15	42.45	41.14
Cut-5	20.70	21.15	26.43	22.76	13.23	16.80	20.25	16.76
Cut-6	25.95	17.40	20.20	21.18	23.40	18.78	22.88	21.68
Cut-7	20.98	25.15	15.55	20.56	15.80	8.40	11.60	11.93
Cut-8	46.00	42.38	40.13	42.83	34.75	29.63	34.50	32.96
Cut-9	61.00	51.00	43.38	51.79	75.13	46.50	64.63	62.08
Cut-10	61.00	51.00	43.38	51.79	50.13	46.50	64.63	53.75
Cut-11	18.00	13.88	11.00	14.29	13.88	13.63	14.25	13.92
Mean	48.74	42.76	35.57	42.36	44.89	38.63	41.04	41.52

Statistical Parameters	F-test	LSD (5%)
Water type	NS	-
Irrigation system	**	4.26
Cuts	**	8.16
Water type × Irrigation system	*	6.02
Water type × Cuts	NS	-
Irrigation system × Cuts	*	14.13
Water type × Irrigation system × Cuts	NS	-
C. V. (%)		34.2

yield of 44.89 t/ha and 538.60 t/ha were obtained under drip irrigation system as compared to 38.63 t/ha and 463.60 t/ha under surface irrigation and 41.04 t/ha and 492.53 t/ha under sub-surface irrigation systems. Similar trends were observed in dry matter yields under irrigation systems and water types. In general, the forage yield levels under treated wastewater were found to be higher than under freshwater. Jun-feng et al. (2007), Khan et al., (2010), Al-Khamisi et al. (2011) and Khan et al. (2012) also found treated wastewater improving the forage yield the crops.

3.4 Water-Use Efficiency (WUE)

In respect of WUE, only the main effect of cut-harvests was found highly significant ($p<0.01$) and interaction effect of water type and irrigation system was significant ($p<0.05$) while all other effects were not found significant ($p>0.05$) (Table 5). The mean WUE with use of treated wastewater (2.33) was similar to that with freshwater (2.36). Among the irrigation systems, WUE of sorghum was significantly higher under drip irrigation than the

Table 4 Means of dry matter yield (t/ha) in sorghum under treated wastewater and freshwater in three irrigation systems

Cuts	Treated wastewater				Fresh water			
	Drip	Surface	Sub surface	Mean	Drip	Surface	Sub surface	Mean
Cut-1	23.09	17.77	11.64	17.50	23.79	24.97	14.36	21.04
Cut-2	17.37	17.60	13.85	16.27	16.53	14.77	13.44	14.91
Cut-3	21.68	19.62	14.74	18.68	22.57	19.79	20.78	21.04
Cut-4	12.76	15.36	12.69	13.60	12.83	11.30	12.34	12.16
Cut-5	6.40	6.17	8.54	7.03	3.59	4.69	6.04	4.77
Cut-6	7.11	5.04	5.47	5.87	6.37	5.55	6.95	6.29
Cut-7	6.13	6.78	4.19	5.70	3.82	2.27	2.88	2.99
Cut-8	12.36	12.42	11.17	11.98	9.21	8.60	9.66	9.16
Cut-9	17.06	15.34	12.78	15.06	22.82	14.20	21.45	19.49
Cut-10	16.80	17.05	13.34	15.73	15.12	14.58	19.87	16.52
Cut-11	5.06	4.98	3.36	4.47	3.96	4.11	4.43	4.17
Mean	13.25	12.56	10.16	11.99	12.78	11.35	12.02	12.05

Statistical parameters	F-test	LSD (5%)
Water type	NS	-
Irrigation system	*	1.27
Cuts	**	2.44
Water type × Irrigation system	*	1.80
Water type × Cuts	*	3.45
Irrigation system × Cuts	*	4.23
Water type × Irrigation system × Cuts	NS	-
C. V. (%)		35.7

Table 5 Means of water use efficiency (WUE) (kg DM/m^3) in sorghum under treated wastewater and fresh water in three irrigation systems

Cuts	Treated wastewater				Fresh water			
	Drip	Surface	Sub surface	Mean	Drip	Surface	Sub surface	Mean
Cut-1	3.21	2.47	1.62	2.43	3.31	3.47	2.00	2.92
Cut-2	2.67	2.71	2.13	2.50	2.54	2.27	2.07	2.29
Cut-3	4.17	3.78	2.84	3.59	4.34	3.80	3.99	4.04
Cut-4	3.65	4.39	3.63	3.89	3.67	3.23	3.53	3.47
Cut-5	1.07	1.03	1.42	1.17	0.60	0.78	1.01	0.80
Cut-6	1.06	0.75	0.82	0.88	0.95	0.83	1.04	0.94
Cut-7	0.77	0.85	0.53	0.71	0.48	0.28	0.36	0.37
Cut-8	1.90	1.91	1.72	1.84	1.42	1.32	1.49	1.41
Cut-9	3.79	3.41	2.84	3.35	5.07	3.16	4.77	4.33
Cut-10	4.80	4.87	3.81	4.49	4.32	4.17	5.68	4.72
Cut-11	0.84	0.83	0.56	0.74	0.66	0.69	0.74	0.70
Mean	2.54	2.45	1.99	2.33	2.49	2.18	2.42	2.36

Statistical parameters	F-test	LSD (5%)
Water type	NS	-
Irrigation system	NS	-
Cuts	**	0.53
Water type × Irrigation system	*	0.39
Water type × Cuts	NS	-
Irrigation system × Cuts	NS	-
Water type × Irrigation system × Cuts	NS	-
C. V. (%)		39.4

other irrigation systems (Table 5) not only with treated wastewater (2.54) but also with freshwater irrigation (2.49) as compared to surface and sub-surface irrigations. Similarly, higher values of water-use efficiencies N level under drip irrigation system in the studies of El-Aref et al. (2005).

Several authors have investigated the response of annual forages under treated wastewater conditions in comparison with freshwater conditions without involving irrigation system. In the earlier studies conducted using treated wastewater, the higher magnitudes of element contents in treated wastewater were

Table 6 (a) Means concentrations (ppm) of Mn, Fe and Zn in sorghum plant samples from plots irrigated by treated wastewater and freshwater under three irrigation systems

Irrigation system	Mn			Fe			Zn		
	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean
Drip	0.170	0.195	0.183	1.065	1.274	1.170	0.149	0.192	0.171
Surface	0.178	0.167	0.173	1.189	1.305	1.247	0.144	0.123	0.134
Sub-surface	0.219	0.177	0.198	1.441	0.979	1.210	0.207	0.208	0.208
Mean	0.189	0.180		1.232	1.186		0.167	0.174	
Statistical analysis	F-test	LSD (5%)		F-test	LSD (5%)		F-test	LSD (5%)	
Water type	NS	-		NS	-		NS	-	
Water quantity	NS	-		NS	-		NS	-	
Water type × Water quantity	NS	-		NS	-		NS	-	
C.V.	14.7			19			66.4		

Table 6 (b) Means concentrations (ppm) of P, Al and Ba in sorghum plant samples from the plots irrigated by treated wastewater and freshwater under three irrigation systems

Irrigation system	P			Al			Ba		
	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean
Drip	3.729	3.834	3.782	0.455	0.427	0.441	0.087	0.090	0.088
Surface	3.621	4.689	4.155	0.491	`0.454	0.473	0.083	0.101	0.092
Sub-surface	3.235	5.357	4.296	0.529	0.437	0.483	0.089	0.084	0.087
Mean	3.528	4.627		0.492	0.439		0.086	0.092	
Statistical analysis	F-test	LSD (5%)			F-test	LSD (5%)		F - test	LSD (5%)
Water type	NS	-		NS	-		NS	-	
Water quantity	NS	-		NS	-		NS	-	
Water type × Water quantity	NS	-		NS	-		NS	-	
C.V.	42.3			17.9			14.9		

Table 6 (c) Means concentrations (ppm) of Cr, Co, Pb and Ti in sorghum plant samples from the plots irrigated by treated wastewater and freshwater under three irrigation systems

Irrigation system	Cr			Co			Pb			Ti		
	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean
Drip	0.065	0.071	0.068	0.065	0.065	0.065	0.173	0.185	0.179	0.031	0.037	0.034
Surface	0.066	0.064	0.065	0.066	0.064	0.065	0.207	0.181	0.194	0.033	0.038	0.035
Sub-surface	0.067	0.062	0.065	0.065	0.063	0.064	0.173	0.184	0.179	0.036	0.022	0.034
Mean	0.066	0.066		0.065	0.064		0.184	0.183		0.033	0.032	
Statistical analysis	F-test	LSD (5%)		F-test	LSD (5%)		F-test	LSD (5%)		F-test	LSD (5%)	
Water type	NS	-		NS	-		NS	-		NS	-	
Water quantity	NS	-		NS	-		NS	-		NS	-	
Water type × Water quantity	NS	-		NS	-		NS	-		*	0.019	
C.V.	11			4.8			16.9			30		

attributed to their higher yields of forage. The forage samples had either low or under the limits of contents of heavy elements that are otherwise deleterious to livestock health and in turn in its products for human use (Jun-feng et al., 2007; Aghtape et al., 2011; Khan et al., 2012). In the present study also, plant samples were analyzed for certain heavy and macro elements studied such as Mn, Fe, Zn, P, Al, Ba, Cr, Co, Pb and Ti. The results of statistical analysis indicated that there were no significant effects of either water type or irrigation system or their interaction on any of the macro and heavy elements studied. The concentrations of

Table 7 Values of macro-elements and heavy elements found in soil samples taken after harvest

Element (mg/kg)	Fresh water				Treated wastewater			
	0-15 cm	15-30 cm	30-60 cm	Mean	0-15 cm	15-30 cm	30-60 cm	Mean
Mn	0.393	0.401	0.377	0.390	0.363	0.332	0.351	0.349
Cd	nd	nd	nd	nd	nd	nd	nd	nd
Cu	0.035	nd	nd	0.035	nd	nd	nd	nd
Fe	1.309	1.355	1.305	1.323	1.194	1.311	1.269	1.258
Zn	0.070	0.086	0.111	0.089	0.046	0.050	0.024	0.040
B	0.011	0.056	0.025	0.031	0.037	0.008	0.024	0.023
P	0.316	0.036	nd	0.176	0.017	nd	nd	0.017
Al	0.039	0.016	0.019	0.025	0.006	0.006	0.002	0.005
Ba	0.136	0.136	0.134	0.135	0.124	0.138	0.143	0.135
Cr	0.045	0.046	0.041	0.044	0.040	0.047	0.040	0.042
Co	0.080	0.084	0.089	0.084	0.077	0.078	0.069	0.075
Pb	0.352	0.291	0.255	0.299	0.241	0.200	0.232	0.224
Ni	0.154	0.177	0.157	0.163	0.128	0.116	0.135	0.126
Ti	0.006	0.007	0.004	0.006	0.003	0.002	0.002	0.002

nd= not detected

Table 8 Mean chemical contents of water samples from treated wastewater and freshwater irrigations taken during experimental period

Parameter	Unit	Treated wastewater	Fresh water
ECw	*dS/m*	0.88	1.06
pH	-	7.7	7.5
Nitrogen N-NO_3^- (nitrate)	*mg/l*	28.7	0.463
Potassium K+	mg/l	22.93	17.83
Sulfate SO_4^{2-}	*mg/l*	81.17	39.87
Bicarbonate HCO_3^-	*mg/l*	107.99	152.53
Carbonate CO_3^-	*mg/l*	Trace	Trace
Calcium Ca^{2+}	*mg/l*	58.21	38.91
Magnesium Mg^{+2}	*mg/l*	20.29	30.01
Sodium Na^+	*mg/l*	94.07	140.07
Chloride Cl^-	*mg/l*	140.02	276.49
Manganese Mn^{+2}	*mg/l*	0.028	0.018
Cadmium Cd^{+2}	*mg/l*	Nd*	Nd*
Copper Cu^+	*mg/l*	Nd*	Nd*
Fe	*mg/l*	0.365	0.337
Zinc Zn^{+2}	*mg/l*	nd	nd
Boron B	*mg/l*	nd	nd
P	*mg/l*	nd	nd
Aluminum Al^{+3}	*mg/l*	0.013	0.011
Barium Ba^{+2}	*mg/l*	0.056	0.054
Chromium Cr^{+2}	*mg/l*	0.047	0.044
Cobalt Co^{+2}	*mg/l*	0.062	0.057
Lead Pb^{4+}	*mg/l*	0.211	0.185
Nickel Ni	*mg/l*	nd	nd
Ti	*mg/l*	0.001	nd

*nd-not detecetd

heavy elements were either very low, low or in trace amount under the limits of toxicity threshold in both plant samples (Tables 6 (a-c)) and soil samples (Table 7) taken after experimentation. Irrigation with treated wastewater has shown increase in concentrations of only three among the elements studied such as in P (4.627 ppm in treated wastewater vs 3.528 in freshwater), Zn (0.174 ppm in treated wastewater vs 0.167 in freshwater) and Ba (0.092 ppm in treated wastewater vs 0.167 in freshwater). This was also found in the recent study of Galavi et al. (2010) where concentrations of Cu and Fe were found increased with irrigation of wastewater and in general concentrations of all elements in plant samples were lower than toxicity threshold.

Present study revealed that forage sorghum can last till 11 cut-harvests spanning 680 days giving total green and dry matter yields of 508.30 t/ha and 143.88 t/ha respectively under treated wastewater irrigation as compared to total green and dry matter yields of 498.26 t/ha and 144.58 t/ha respectively under freshwater irrigation (Tables 3 and 4; Figure 1). The sorghum crop appeared to respond favorably under summer conditions >27^o C as compared to its response in winter as evidenced by higher green and dry matter yields obtained in cut-harvests, 1, 2 and 3 taken during 2013 to the extent of 65.72 t/ha @938.84 kg/ha/day, 55.71 t/ha @1295.67 kg/ha/day and 76.06 t/ha @ 2001.53 kg/ha/day, respectively. Similar trend was observed in cut-harvests 8, 9 and 10 taken during 2014 which were out of growth and development due to high temperatures prevailed during the period (Table 9). However, the forage yields were of lower magnitude due older age of crop stand. Summer conditions

Table 9 Means of per day green and dry matter yields in different cut-harvests in sorghum during experimental period

Cuts	Harvesting date	Cut duration (days)	Green yield (kg/ha/day)	Dry yield (kg/ha/day)
Cut-1	**1-Jul-2013**	**70**	**938.84**	**275.27**
Cut-2	**13-Aug-2013**	**43**	**1295.67**	**362.60**
Cut-3	**21-Sep-2013**	**38**	**2001.53**	**522.66**
Cut-4	**23-Dec-2013**	**93**	**480.69**	**138.48**
Cut-5	**1-Mar-2014**	**66**	**299.36**	**89.42**
Cut-6	**27-Apr-2014**	**57**	**376.02**	**106.68**
Cut-7	**11-Jun-2014**	**44**	**369.23**	**98.68**
Cut-8	**13-Aug-2014**	**62**	**611.23**	**170.45**
Cut-9	**16-Oct-2014**	**63**	**903.78**	**274.17**
Cut-10	**8-Dec-2014**	**51**	**1034.73**	**316.18**
Cut-11	**16-Mar-2015**	**97**	**145.40**	**44.51**

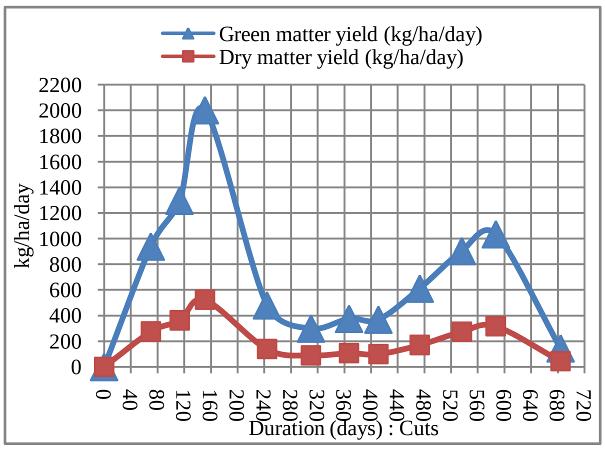

Fig 1 Per day green and dry matter yields (kg/ha/day) in different cut harvests in sorghum Table 9 Means of per day green and dry matter yields in different cut-harvests in sorghum during experimental period

were in general found to advance crop growth towards flowering earlier than winter conditions in case of monocot-forage crops like sorghum. This phenomenon is common in all grass species as was also found in Rhodes grass species in various cuts year round by Nadaf et al., 2009a and Nadaf et al., 2009b.

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Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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