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PRODUCTIVITY OF FORAGE TRITICALE GENOTYPES UNDER TREATED WASTEWATER AND FRESH WATER IRRIGATION

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ABSTRACT

Triticale is one of the most important recently adopted drought-tolerant crops in semi-arid tropic regions of the world including Oman. Eleven forage genotypes of triticale selected based on their superiority for forage yield under normal irrigation water conditions were investigated for response to treated wastewater and fresh water irrigation in respect of productivity during winter seasons of 2012 and 2013 (November-January) under drip irrigation at Agriculture Research Station, Rumais. The results showed that main effect of years was highly significant ($p<0.01$) for all the characters studied. However, the effect of accessions was significant ($p<0.05$) for plant height and number of tillers whereas that of water types was significant ($p<0.05$) for number of tillers and green matter yield. Among the interactions, effect of year x variety was highly significant ($p<0.01$) for only green matter yield while that of year x water type was significant ($p<0.05$) for three characters namely plant height (cm), green and dry matter yields. Irrespective of water types, both green matter and dry matter yields in 2013 (20.22 and 7.94 t/ha) was significantly higher than those in 2012 (11.56 and 2.50 t/ha). In both years, the green and dry matter yields were either non-significantly ($p>.05$) or significantly ($p<0.05$) higher under freshwater conditions than under treated wastewater conditions. All the heavy elements were in low concentrations in both plant and soil samples after crop harvest. The growth parameters of triticale were stable during irrigation by treated wastewater with no adverse impact on chemical characteristics in plant or water

Keywords: Treated wastewater, Freshwater, Growth attributes, Forage yield, Triticale

INTRODUCTION

In almost all arid and semi-arid countries, nowadays scarcity of water is being partially addressed through the use of treated wastewater (TW). This also helps to protect the environment from pollution as TW is claimed to have no risk to the plants, groundwater or human health. (Agunwamba, 2001; Anderson et al., 2001; Sipala et al., 2003; Ling et al., 2011; Khan et al., 2012). TW is being widely used for irrigation in many continues as alternative to available water for irrigation to overcome the problems of water stress (Al-Rashed and Sherif, 2000; Oron, et al., 2007; Aghtape, et al., 2011; Alkhamisi et al., 2011; Khan et al., 2012). Recently triticale (Triticum aestivum x Secale cereale) is considered and recommended as one of the most important drought-tolerant crops in semi-arid tropic regions of the world (Abdelly et al., 2008) including Oman where it is one of the introduced crops during winter season to be grown as fodder (Akhtar and Nadaf, 2002). It requires relatively less irrigation due to its short growing season for fodder. Taller varieties in general produced more fodder yield than the short ones (Akhtar and Nadaf, 2002; Mergaoum et al., 2009; Alkhamis et al., 2011). Triticale fodder is often considered highly palatable and a good source of protein, minerals and energy (Mergaoum et al., 2009; Chenini, 2009; Alkhamis et al., 2011). The present study has an objective to assess the potential of treated wastewater available from STPs (Sewage Treatment Plant) in the country for the growth of triticale in producing higher yield of fodder in comparison with that by use of available freshwater (FW) without deleterious elements in fodder.

2. MATERIALS AND METHODS

The experiment was laid in two consecutive winter seasons of 2012-13 and 2013-14 under modified split-plot in RCBD with Water Type as main factor viz. Freshwater (FW) and Treated wastewater (TW)) and eleven genotypes/ varieties of triticale as sub factor. Seeds of triticale genotypes were planted in plots consisting of four 3m rows at 25 cm between rows and 15 cm between plants in each water type during middle of November and harvested in January as these varieties took 55-60 days to attain 20 to 50 % blooming period, when the crop was usually cut for green forage. Plots were irrigated for half hour three times every week and fertilized at 100:90:60 kg NPK/ha as per national recommendations (Akhtar and Nadaf, 2002). At fodder harvest, the observations were recorded on plant height (cm), number of tillers/50cm and green matter weight (kg/m2). The green fodder samples were taken at random for each genotype for determination of dry matter content (AOAC, 1984). The data were subjected to analysis of variance according to Gomez and Gomez (1984) using statistical software MStat-C.

3. RESULTS AND DISCUSSION

Tables 1 to 4 present the means of characters of eleven triticale genotypes recorded during winter seasons of 2012- 13 and 2013-14 along with means over years, respectively. The results showed that main effect of years was highly significant ($p<0.01$) for all the characters studied. However, the effect of accessions was significant ($p<0.05$) for plant height and number of tillers whereas that of water types was significant ($p<0.05$) for number of tillers and green matter yield. Among the interactions, effect of year x variety was highly significant ($p<0.01$) for only green matter yield while that of year x water type was significant ($p<0.05$) for three characters namely plant height (cm), green and dry matter yields.

Plant height:

The mean value of the plant height of the genotypes was significantly higher in winter 2012 (96.86 cm) than that in winter 2013 (75.71 cm) (Table 1). The values of plant height in both the years as well their means over the years under TWW were not significantly ($p<0.05$) higher than those under FW. The genotype PI 388665 was numerically ($p>0.05$) superior (91.33 cm) in TW while it was significantly taller (95.00 cm) under FW to other genotypes studied (Table 1). Among all the genotypes, three genotypes showed differential performance in water types i.e. PI 429162, PI 520437 and PI 429060 had higher plant height under TW (86.50 cm, 90.50 cm and 89.00 cm) than under FW (71.67 cm, 77.50 cm and 80.17 cm, respectively). Such increase in plant height under treated wastewater conditions was also seen earlier in crops like pearl millet (Khan et al., 2012), maize and other cereal fodder crops (Agunwamba, 2001; Al-Khamisi et al., 2011).

Number of tillers/50 cm

The results indicated that only the effects of main factors viz. year, water type and genotypes were significant ($p<0.05$) whereas all other effects like those of interactions were found non-significant ($p>0.05$) (Table 2). The mean value of number of tillers under FW (18.68) was found to be significantly ($p<0.05$) higher than that under TW (17.53). Similar trend was insignificantly ($p>0.05$) found in both the years. Among the genotypes, only PI 429209 had a differential performance with higher extent in TW (19.00) than that in FW (16.17). The rest of the genotypes however had superior performance in FW either significantly ($p<0.05$) or insignificantly ($p>0.05$).

Green and dry matter yields (t/ha)

The results indicated that only the effects of two main factors viz. year and water type and two interactions viz. year x variety and year x water type were significant ($p<0.05$) whereas all other effects like those of interactions were found non-significant ($p>0.05$). In both the years the green matter yield of genotypes under FW conditions was significantly ($p<0.05$) (2013- 22.36t/ha) or insignificantly ($p>0.05$) (2012- 11.62 t/ha) more than that under TW conditions (2012- 11.51 t/ha and 2013- 18.08 t/ha) as the same was reflected in the mean values over the years with significance ($p<0.05$) (FW-16.99 t/ha and TW- 14.79 t/ha). The higher yields of the genotypes during 2013 were attributed to higher number of tillers/ 50cm perhaps because of higher fertility of experimental soil. In respect of genotypes, all the genotypes showed significantly ($p<0.05$) superior performance under FW than under TW. However, some genotypes like PI 520437, PI 525485 and PI 429060 which produced significantly ($p<0.05$) or insignificantly higher green matter yield under TW (16.14, 16.60 and 1483 t/ha, respectively) than that under FW (13.32, 16.24 and 13.84 t/ha, respectively). These genotypes also showed similar differential performance with respect to plant height, number of tillers and dry matter yield.

The results of dry matter yield of triticale genotypes indicated that only the main effect of year and the interaction effect of year x water type were highly significant ($p<0.01$). In 2012 the dry matter yield of genotypes under treated wastewater conditions was non-significantly ($p>0.05$) more than that under fresh water conditions whereas in 2013 the trend was significantly reverse ($p<0.05$). Among the genotypes, in terms of mean values over the years and water-types, PI 429101 was the highest in dry matter yield (5.81 t/ha) which was followed by PI 429209 (5.80 t/ha), PI 388665 (5.33 t/ha), PI 429060 (5.33 t/ha) and PI 429166 (5.32 t/ha).

Several authors have investigated previously on the response of annual forages under TW conditions in comparison with FWr conditions and demonstrated the merits of treated wastewater conditions in providing higher yields of forage (Khan et al., 2012, Feng-jun et al., 2007; Aghtape et al., 2011; Alkhamis et al., 2011). In the present study, the majority of tested genotypes responded very well in performance under FW. This could be attributed to the genetic capability to respond favourably under soil / water with minimal nutritional status in comparison with that exists under TW conditions. However, some genotypes like PI 520437, PI 429060, PI 429152 and PI 429162 responded significantly ($p<0.05$) positive under TW either in growth (plant height and no. of tiller) or in yield (green & dry matter yields) characters. It is known fact that vegetative characters like plant height and no. of tillers are mainly influenced by NPK and organic matter, which are adequately available in treated wastewater which improves the plant growth. This is evident from the fact that three major elements viz. N, P and K were found in higher concentrations in treated wastewater (N – 28.70 mg/l; P – 9.41 mg/l and K –22.93 mg/l) than in fresh water ((N – 0.463 mg/l; P – 0 mg/l and K – 17.83 mg/l) in the present experiment (Table 5). Mekki et al., (2006) found that applying treated wastewater could increase the population of soil microorganisms that assist in nutrient availability of plants.

In general, it was observed in the literature that plant samples of the forage produced under TW were with 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 (Khan et al., 2012, Feng-jun et al., 2007; Aghtape et al., 2011; Alkhamis et al., 2011). In the present study also all the heavy and micro elements studied viz. V, Co, Cd, Mo, Pb, Cu, Cr, Mn, Ni and Zn were either very low, low or in trace amount under the limits in either water samples used or plant samples studied (Tables 5 and 6).

CONCLUSION:

It was concluded that among the fodder triticale genotypes investigated some genotypes like PI 520437, PI 525485 and PI 429060 were positively superior in plant height, number of tillers, green and dry matter yields. These are suggested to be tried in advanced and pilot trials for their future recommendation for general cultivation under TW conditions in Oman.

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Table 1. Means of plant height (cm) of 11 triticale accessions under TW and FW conditions in 2012 and 2013

Name of Accession	2012			2013			Mean		
	TW	FW	Mean	TW	FW	Mean	TW	FW	Mean
PI 388665	106.67	112.67	109.67	76.00	77.33	76.67	91.33	95.00	93.17
PI 405026	105.00	98.33	101.67	73.33	75.00	74.17	89.17	86.67	87.92
PI 4290101	95.00	102.33	98.67	66.67	81.00	73.83	80.83	91.67	86.25
PI 520437	107.67	83.67	95.67	73.33	71.33	72.33	90.50	77.50	84.00
PI 520485	103.00	87.00	95.00	71.67	85.33	78.50	87.33	86.17	86.75
PI 429060	100.33	94.67	97.50	77.67	65.67	71.67	89.00	80.17	84.58
PI 429152	94.00	95.00	94.50	74.33	66.33	70.33	84.17	80.67	82.42
PI 429153	98.00	92.00	95.00	80.33	86.00	83.17	89.17	89.00	89.08
PI 429162	96.67	81.67	89.17	76.33	61.67	69.00	86.50	71.67	79.08
PI 429166	94.67	96.00	95.33	78.33	82.67	80.50	86.50	89.33	87.92
PI 429209	95.00	91.67	93.33	80.33	85.00	82.67	87.67	88.33	88.00
Mean	**99.64**	**94.09**	**96.86**	**75.30**	**76.12**	**75.71**	**87.47**	**85.11**	**86.29**

Statistical Analyses

	df	Mean square	F-test	(5%)	(%)
Rep	2	267.667	-	-	
Year	1	14763.76	**	3.16	
Variety	10	166.339	*	7.40	
Water type	1	184.364	NS	-	
Year * Variety	10	146.791	NS	-	10.6
Year * Water type	1	334.091	*	4.46	
Variety * Water type	10	169.43	*	10.47	
Year * Variety * Water type	10	104.191	NS	-	
Error	86	83.256			
Total	131				

Table 2. Means of number of tillers/ 50 cm row length of 11 triticale accessions under TW and FW conditions in 2012 and 2013

Name of Accession	2012			2013			Mean		
	TW	**FW**	**Mean**	**TW**	**FW**	**Mean**	**TW**	**FW**	**Mean**
PI 388665	14.67	16.00	15.33	22.00	19.00	20.50	18.33	17.50	17.92
PI 405026	18.67	20.00	19.33	21.33	21.33	21.33	20.00	20.67	20.33
PI 4290101	17.67	18.33	18.00	22.00	23.67	22.83	19.83	21.00	20.42
PI 520437	11.00	15.00	13.00	22.67	22.33	22.50	16.83	18.67	17.75
PI 520485	11.00	16.67	13.83	22.00	22.33	22.17	16.50	19.50	18.00
PI 429060	10.67	13.67	12.17	19.33	22.00	20.67	15.00	17.83	16.42
PI 429152	11.00	14.67	12.83	23.67	21.67	22.67	17.33	18.17	17.75
PI 429153	11.67	15.00	13.33	20.67	22.67	21.67	16.17	18.83	17.50
PI 429162	11.33	15.33	13.33	21.33	21.00	21.17	16.33	18.17	17.25
PI 429166	13.67	14.00	13.83	21.33	24.00	22.67	17.50	19.00	18.25
PI 429209	17.00	10.00	13.50	21.00	22.33	21.67	19.00	16.17	17.58
Mean	**13.49**	**15.33**	**14.41**	**21.58**	**22.03**	**21.80**	**17.53**	**18.68**	**18.11**

Statistical Analyses

	df	Mean square	F-test	LSD (5%)	C.V. (%)
Rep	2	1.485			
Year	1	1804.121	**	1.03	
Variety	10	17.818	*	2.42	
Water type	1	43.758	*	1.03	
Year * Variety	10	17.055	NS	-	
Year * Water type	1	16.03	NS	-	
Variety * Water type	10	8.924	NS	-	
Year * Variety * Water type	10	13.13	NS	-	
Error	86	8.911			
Total	131				

Table 3. Means of green matter yield (t/ha) of 11 triticale accessions under TW and FW conditions in 2012 and 2013

Name of Accession	2012			2013			Mean		
	TW	FW	Mean	TW	FW	Mean	TW	FW	Mean
PI 388665	13.66	19.11	16.39	14.92	21.13	18.03	14.29	20.12	17.21
PI 405026	14.33	17.00	15.66	16.70	22.35	19.53	15.52	19.67	17.59
PI 4290101	14.55	18.00	16.27	15.00	22.33	18.67	14.78	20.17	17.47
PI 520437	14.83	7.33	11.08	17.45	19.30	18.38	16.14	13.32	14.73
PI 520485	13.00	8.67	10.83	16.67	19.02	17.84	14.83	13.84	14.34
PI 429060	12.44	11.38	11.91	20.75	21.10	20.93	16.60	16.24	16.42
PI 429152	7.66	8.66	8.16	19.50	23.83	21.67	13.58	16.25	14.91
PI 429153	8.00	8.50	8.25	16.83	24.02	20.43	12.42	16.26	14.34
PI 429162	9.33	5.33	7.33	21.52	23.92	22.72	15.42	14.62	15.02
PI 429166	8.66	10.83	9.75	19.42	25.62	22.52	14.04	18.22	16.13
PI 429209	10.17	13.00	11.58	20.10	23.33	21.72	15.13	18.17	16.65
Mean	**11.51**	**11.62**	**11.56**	**18.08**	**22.36**	**20.22**	**14.79**	**16.99**	**15.89**

Statistical Analyses

Source of variance	df	Mean square	F-test	LSD (5%)	C.V. (%)
Rep	2	128.881			
Year	1	2471.22	**	1.73	
Variety	10	19.11	NS	-	
Water type	1	158.885	*	1.73	
Year * Variety	10	64.947	**	5.75	31.5
Year * Water type	1	143.813	*	2.45	
Variety * Water type	10	25.714	NS	-	
Year * Variety * Water type	10	6.004	NS	-	
Error	86	25.115			
Total	131				

Table 4. Means of dry matter yield (t/ha) of 11 triticale accessions under TW and FW conditions in 2012 and 2013

Name of Accession	2012			2013			Mean		
	TW	FW	Mean	TW	FW	Mean	TW	FW	Mean
PI 388665	3.37	3.07	3.22	5.50	9.38	7.44	4.44	6.23	5.33
PI 405026	3.04	2.57	2.81	5.92	8.39	7.16	4.48	5.48	4.98
PI 4290101	4.64	3.20	3.92	5.67	9.73	7.70	5.16	6.46	5.81
PI 520437	4.33	1.37	2.85	6.97	7.09	7.03	5.65	4.23	4.94
PI 520485	3.76	1.65	2.70	6.76	7.06	6.91	5.26	4.35	4.81
PI 429060	3.10	2.31	2.70	7.95	7.98	7.96	5.52	5.14	5.33
PI 429152	1.98	1.31	1.65	5.56	10.59	8.08	3.77	5.95	4.86
PI 429153	1.82	1.80	1.81	7.24	9.52	8.38	4.53	5.66	5.09
PI 429162	0.55	1.14	0.85	8.72	10.16	9.44	4.64	5.65	5.14
PI 429166	2.11	2.47	2.29	7.31	9.41	8.36	4.71	5.94	5.32
PI 429209	2.77	2.63	2.70	8.77	9.02	8.90	5.77	5.83	5.80
Mean	**2.86**	**2.14**	**2.50**	**6.94**	**8.94**	**7.94**	**4.90**	**5.54**	**5.22**

Statistical Analyses

Source of variance	df	Mean square	F-test	LSD (5%)	C.V. (%)
Rep	2	14.288			
Year	1	977.08	**	0.73	
Variety	10	1.412	NS	-	
Water type	1	13.37	NS	-	
Year * Variety	10	6.524	NS	-	40.2
Year * Water type	1	60.914	**	1.03	
Variety * Water type	10	3.906	NS	-	
Year * Variety * Water type	10	2.454	NS	-	
Error	86	4.398			
Total	131				

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Table 5. Mean chemical constituents samples of two types of water used for irrigation

Parameter	Unit	Fresh water	Treated wastewater
ECw	***dS/m***	1.06	0.88
pH	-	7.5	7.7
Nitrogen N-NO_3	***mg/l***	0.463	28.70
Phosphorus P^{3-}	***mg/l***	Nd	9.413
Potassium K^+	***mg/l***	17.83	22.93
Cations &Anions (mg/l)			
Sulfate SO_4^{2-}	***mg/l***	39.87	81.17
Bicarbonate HCO_3^-	***mg/l***	152.53	107.99
Carbonate CO_3	***mg/l***	Trace	Trace
Calcium Ca^{2+}	***mg/l***	38.91	58.21
Magnesium Mg^{+2}	***mg/l***	30.01	20.29
Sodium Na^+	***mg/l***	140.07	94.07
Chloride Cl^-	***mg/l***	276.49	140.02
Zinc Zn^{+2}	***mg/l***	0.461	0.546
Copper Cu^+	***mg/l***	0.026	0.027
Manganese Mn^{+2}	***mg/l***	0.011	0.048
Nickel Ni	***mg/l***	0.04	0.019
Boron B	***mg/l***	1.269	0.799
Molybdenum Mo	***mg/l***	0.083	0.112
Silicon Si	***mg/l***	0.974	0.959
Vanadium V	***mg/l***	0.064	0.043
Cobalt Co^{+2}	***mg/l***	0.320	0.250
Lead Pb^{4+}	***mg/l***	Nd	Nd
Chromium Cr^{+2}	***mg/l***	Nd	Nd
Cadmium Cd^{+2}	***mg/l***	Nd	Nd
Copper Cu^+	***mg/l***	Nd	Nd
Barium Ba^{+2}	***mg/l***	0.069	0.072
Sulfide S^{-2}	***mg/l***	5.581	22.97
Aluminum Al^{+3}	***mg/l***	0.096	0.093

Nd= Not detected

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Table 6. Means of concentrations of various elements found in plant samples under treated wastewater and fresh water irrigation after the experiment

Elements (ppm)	Treated wastewater			Fresh water		
	2012	**2013**	**Mean**	**2012**	**2013**	**Mean**
B	80.88	95.63	88.25	114.73	134.83	124.78
Al	259.50	316.00	287.75	262.25	321.50	291.88
V	0.78	0.95	0.86	1.78	2.13	1.95
Cr	6.20	7.45	6.83	11.68	13.98	12.83
Mn	15.98	19.23	17.60	18.08	22.05	20.06
Fe	320.75	383.25	352.00	327.00	394.50	360.75
Co	0.33	0.30	0.31	0.28	0.35	0.31
Ni	7.40	8.70	8.05	6.18	7.28	6.73
Cu	4.98	5.80	5.39	7.33	8.63	7.98
Zn	131.38	153.50	142.44	124.58	146.18	135.38
Mo	1.58	1.75	1.66	3.75	4.33	4.04
Cd	0.15	0.15	0.15	0.18	0.18	0.18
Pb	2.28	2.50	2.39	11.80	12.98	12.39