

Response of Selected Forage Pearl Millet Genotypes to Treated Wastewater and Fresh Water Irrigation for Productivity

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Abstract – The utilization of treated wastewater has not only advantage of solving water scarcity problem in agriculture but also it is expected to protect the environment by reducing the pollution load with little or no risk to the plants, groundwater or human health. Pearl millet (*Pennisetum glaucum* [L.] R.Br.) is one of the most important drought-tolerant crops in semi-arid tropic regions of the world including Oman where it is one of the important summer cereal crops. It requires relatively low irrigation due to its short growing season for fodder. Eleven forage genotypes of pearl millet which were selected based on their superiority for forage yield under normal irrigation water conditions were investigated for their response to treated wastewater and normal irrigation water conditions in respect of productivity consecutively for two consecutive years during summer seasons of 2012 and 2013 (March-May) under drip irrigation at Agriculture Research Station, Rumais. The results indicated main effects of year was significant ($p < 0.05$) to highly significant ($p < 0.01$) with respect to all characters under study except green matter yield while that of water type was significant ($p < 0.05$) for all the characters except chlorophyll content. The effect of genotypes was significant for only plant height ($p < 0.01$) and dry matter yield ($p < 0.05$). Interaction effect of year and genotypes was significant for plant height ($p < 0.01$) and green matter yield ($p < 0.01$) while that of year and water type was significant ($p < 0.05$) only for chlorophyll content. However, interaction effect of two factors viz. genotypes and water type and effect of three factors were non-significant ($p > 0.05$). The highest green matter yield was observed during the years 2013 and 2012 (51.26t/ha and 51.15 t/ha, respectively) with no significant differences under treated wastewater. There were significant differences between years in relation to the dry matter yield. The dry matter yield in the first year (2012; 19.82 t/ha) was significantly higher than that in the second year (2013; 12.42 t/ha). In both the years, the green and dry matter yields were higher under treated water conditions than under fresh water conditions due to its higher nutritional status. The random samples of plant and soil after harvest assisted in investigating the impact of the use of treated wastewater on the plant and soil. The results showed that all the heavy elements were in low concentrations in both plant and soil samples after the harvest of pearl millet crop. In conclusion, the growth parameters of pearl millet were found increased during irrigation by treated wastewater with no adverse impact on chemical characteristics in either plant or soil.

Keywords – Forage Yield, Freshwater, Treated Waste Water, Growth Attributes, Pearl Millet (*Pennisetum Glaucum* L).

I. INTRODUCTION

The utilization of treated wastewater has not only advantage of solving water scarcity problem in agriculture but also it is expected to protect the environment by reducing the pollution load with little or no risk to the plants, groundwater or human health. However, its application warrants effective treatment to protect public health and environment at an affordable cost [1-5].

The problem of fresh water scarcity is common in all the arid and semi arid regions of the world. The problem becomes further acute in the countries that have agro-based economy. Treated wastewater is being widely applied for irrigation in many countries as alternative to available water for irrigation to surmount the problems of water scarcity [5, 6-8].

Pearl millet (*Pennisetum glaucum* [L.] R.Br.) is one of the most important drought-tolerant crops in semi-arid tropic regions of the world including Oman where it is one of the important summer cereal crops [9]. It requires relatively low irrigation due to its short growing season for fodder. Taller varieties in general produced more fodder yield than the short ones [9-10]. Pearl millet fodder is often considered highly palatable and a good source of protein, minerals and energy [11].

The present study was intended to explore the potential of treated wastewater available from STPs (Sewage Treatment Plant) in the country for the growth of pearl millet in producing higher yield of fodder in comparison with that by use of fresh available water with no deleterious elements in fodder.

II. MATERIALS AND METHODS

The experiment was laid in two consecutive summer seasons of 2012 and 2013 under modified split-plot in RCBD with Water Type as main factor viz. Fresh water and Treated wastewater) and eleven genotypes/ varieties of pearl millet as sub factor. Seeds of pearl millet 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 April and harvested in June as these varieties took 45-55 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 100:50:50 kg NPK/ha as per national recommendations [9]. At fodder harvest, the observations were recorded on plant height (cm) and green matter weight (kg/m^2). The green fodder samples were

taken at random for each genotype for determination of dry matter content [10]. SPAD values of leaf samples were also measured by use of SPAD-502 meter that produce relative SPAD meter values, which are proportional to the amount of chlorophyll present in the leaf chlorophyll content [4].

III. RESULTS AND DISCUSSION

Tables 1 to 4 present the means of characters of eleven pearl millet genotypes recorded during summer seasons of 2012 and 2013 along with means over years, respectively. The results indicated main effects of year was significant ($p < 0.05$) to highly significant ($p < 0.01$) with respect to all characters under study except green matter yield while that of water type was significant ($p < 0.05$) for all the characters except chlorophyll content. The effect of genotypes was significant for only plant height ($p < 0.01$) and dry matter yield ($p < 0.05$). Interaction effect of year and genotypes was significant for plant height ($p < 0.01$) and green matter yield ($p < 0.01$) while that of year and water type was significant ($p < 0.05$) only for chlorophyll content. However, interaction effect of two factors viz. genotypes and water type and effect of three factors were non-significant ($p > 0.05$).

Plant Height:

The grand mean value of the plant height of the genotypes was significantly higher in summer 2013 (191.30 cm) than that in summer 2012 (158.70 cm) (Table 1) as mean values over water types in 2013 were more than those in 2012. The values of plant height in both the years as well their means over the years under treated wastewater (161.82 cm, 195.76 cm and 178.79 cm) were significantly ($p < 0.05$) higher than those under fresh water (155.58 cm, 186.85 and 171.21 cm). In general, mean values of plant height of genotypes were significantly ($p > 0.05$) higher under treated wastewater than under fresh water conditions. In summer 2012, irrespective of water types, IP 22269 was significantly highest in plant height (192.17 cm) followed by IP 19612 (180.50 cm), IP 13150 (171.00 cm), IP 6104 (170.67 cm) and Sudan Pop I (162.17 cm) whereas in summer 2013 Sudan Pop I was significantly tallest (200.00 cm) followed by IP 22269 (197.17 cm), Sudan Pop III (194.83 cm), IP 19586 B3 (193.33 cm) and IP 6110 (192.17 cm) as compared to other genotypes. As regards mean values over the years, irrespective of water types, IP 22269 (194.67 cm) had highest plant height followed by IP 19612 (185.25 cm), Sudan Pop I (181.08 cm), IP 6104 (180.17 cm) and IP 13150 (176.50 cm). In respect of performance of genotypes under treated wastewater conditions, 22269 (193.50 cm) recorded highest plant height followed by IP 6104 (189.17 cm), IP 19586 B3 (188.50 cm), IP 19612 (185.50 cm) and Sudan Pop I (180.50). Similar trend in response of genotypes to water types were observed in both the years. Such increase in plant height under treated wastewater conditions was also observed previously not only in pearl millet [5] but also in maize and other cereal fodder crops [1, 12]. The vegetative characters like plant height 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 soil after harvest of the crop under treated wastewater conditions (N – 313.0 $\mu\text{g}/\text{kg}$; P – 68.5 $\mu\text{g}/\text{kg}$ and K – 50.0 $\mu\text{g}/\text{kg}$) than under fresh water irrigation ((N – 296.5 $\mu\text{g}/\text{kg}$; P – 60.2 $\mu\text{g}/\text{kg}$ and K – 45.0 $\mu\text{g}/\text{kg}$) in the present experiment (Table 5). It was observed in 2006 that the use of treated wastewater could increase the density of soil microorganisms that assist in nutrient availability of plants [13].

Chlorophyll Content (SPAD Values)

It has been reported that leaf color indicates the amount and proportion of chlorophyll in leaves which are, in turn, closely related to plant nutrient status. Therefore, leaf colour, as a function of chlorophyll content, can be used as an index to diagnose nutrient status. In the present study, SPAD values recorded for chlorophyll have been used for interpretation of results. The results indicated that the effects of all the factors and their interaction were not significant ($p > 0.05$) except that of year ($p < 0.01$) and year x genotypes ($p < 0.05$), which were significant to highly significant. The mean value of SPAD under treated wastewater conditions in 2013 (52.50) was about one and half times more than that in 2012 (35.45) indicating that nutritional status of plants in general of all the genotypes in 2013 was higher than that in 2012. The conditions of treated wastewater, however, did not have any influence in elevating SPAD values of the plants of all the genotypes under study.

Green and Dry Matter Yields (t/ha):

The results indicated that only the effects of water type and year x water type were significant ($p < 0.05$) whereas the effects of rest were found non-significant ($p > 0.05$). In both the years the green matter yield of genotypes under treated wastewater conditions was significantly ($p < 0.05$) more than that under fresh water conditions as the same is reflected in the mean values over the years. In both the years, mean green matter yield of all the genotypes under treated wastewater was significantly higher to the extent of 51.15 to 51.26 t/ha than that under fresh water conditions (41.13 to 44.78 t/ha). This was also reflected in the mean values over the years.

The results of the experiments in terms of dry matter yield of pearl millet genotypes indicated that only the main effects of year, varieties and water type were significant ($p < 0.05$) to highly significant ($p < 0.01$) whereas the interaction effects were non-significant ($p > 0.05$). In both the years the dry matter yield of genotypes under treated wastewater conditions was significantly ($p < 0.05$) more than that under fresh water conditions as the same was reflected in the mean values over the years. Just like in green matter yield, in both the years, mean dry matter yield of all the genotypes under treated wastewater was significantly higher to the extent of 12.42 to 19.82 t/ha than that under fresh water conditions (10.70 to 15.78 t/ha). This was also reflected in the mean values over the years. Earlier studies also reported that treated wastewater improves the yield of pearl millet [5, 14]. Among the varieties, in terms of mean values over the years, IP 22269

was significantly highest in dry matter yield (20.93 t/ha) which was followed by IP19586 B3 (17.48 t/ha), IP 19612 (16.30 t/ha), Sudan Pop III (15.31 t/ha) and IP 6104 (15.16 t/ha). This trend was also found in the response of genotypes in both the years.

Several authors have studied earlier on the response of annual forages under treated wastewater conditions in comparison with freshwater conditions and demonstrated the merits of treated wastewater conditions in providing higher yields of forage with 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 [5, 8, 15]. 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 both plant and soil samples taken after the harvest of the crop in both the years, 2012 and 2013 (Tables 6 and 7).

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Table 1. Means of plant height (cm) of eleven pearl millet genotypes in two summer seasons under fresh (FW) and treated wastewater (TW) irrigation conditions

Genotypes	Summer 2012			Summer 2013			Mean		
	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean
MC94C2	135.00	133.33	134.17	172.00	203.33	187.67	153.50	168.33	160.92
IP 6104	165.67	175.67	170.67	176.67	202.67	189.67	171.17	189.17	180.17
IP 6110	149.00	158.00	153.50	187.67	196.67	192.17	168.33	177.33	172.83
IP 13150	161.67	180.33	171.00	185.00	179.00	182.00	173.33	179.67	176.50
IP 19612	175.00	186.00	180.50	195.00	185.00	190.00	185.00	185.50	185.25
IP 19586 B3	157.33	175.33	166.33	185.00	201.67	193.33	171.17	188.50	179.83
IP 22269	198.33	186.00	192.17	193.33	201.00	197.17	195.83	193.50	194.67
Sudan Pop I	158.33	166.00	162.17	205.00	195.00	200.00	181.67	180.50	181.08
Sudan Pop III	132.00	135.33	133.67	192.33	197.33	194.83	162.17	166.33	164.25
ICMV155 original	137.33	134.33	135.83	181.67	190.33	186.00	159.50	162.33	160.92
ICMS 7704	141.67	149.67	145.67	181.67	201.33	191.50	161.67	175.50	168.58
Mean	155.58	161.82	158.70	186.85	195.76	191.30	171.21	178.79	175.00

Statistical Parameters

Source of Variation	df	F-test	LSD (5%)
Replication	2	-	-
Year	1	**	6.82
Varieties	10	**	16.00
Water type	1	*	6.82
Year*Varieties	10	**	22.63
Year*Water type	1	NS	-
Varieties*Water type	10	NS	-
Year*Varieties*Water type	10	NS	-
Error	86	NS	-
Total	131		

Table 2. Means of Chlorophyll contents in terms of SPAD values of eleven pearl millet genotypes in two summer seasons under fresh (FW) and treated wastewater (TW) irrigation conditions

Genotypes	Summer 2012			Summer 2013			Mean		
	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean
MC94C2	33.00	35.33	34.17	53.00	55.33	54.17	43.00	45.33	44.17
IP 6104	31.67	36.00	33.83	51.33	53.33	52.33	41.50	44.67	43.08
IP 6110	44.67	36.67	40.67	54.00	54.00	54.00	49.33	45.33	47.33
IP 13150	34.33	23.00	28.67	54.33	48.00	51.17	44.33	35.50	39.92
IP 19612	40.33	35.67	38.00	51.33	53.33	52.33	45.83	44.50	45.17
IP 19586 B3	51.00	39.00	45.00	51.00	53.67	52.33	51.00	46.33	48.67
IP 22269	32.67	28.00	30.33	51.67	51.00	51.33	42.17	39.50	40.83
Sudan Pop I	35.33	33.00	34.17	51.67	50.00	50.83	43.50	41.50	42.50
Sudan Pop III	38.67	34.67	36.67	51.67	53.33	52.50	45.17	44.00	44.58
ICMV155 original	37.00	30.33	33.67	53.00	54.33	53.67	45.00	42.33	43.67
ICMS 7704	34.00	35.67	34.83	52.33	53.33	52.83	43.17	44.50	43.83
Mean	37.52	33.39	35.45	52.30	52.70	52.50	44.91	43.05	43.98

Statistical Parameters

Source of Variation	df	F-test	LSD (5%)
Replication	2	-	-
Year	1	**	2.24
Varieties	10	NS	-
Water type	1	NS	-
Year*Varieties	10	NS	-
Year*Water type	1	*	3.17
Varieties*Water type	10	NS	-
Year*Varieties*Water type	10	NS	-
Error	86		
Total	131		

Table 3. Means of green matter yield (t/ha) of eleven pearl millet genotypes in two summer seasons under fresh (FW) and treated wastewater (TW) irrigation conditions

Genotypes	Summer 2012			Summer 2013			Mean		
	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean
MC94C2	28.52	35.33	31.93	33.28	55.37	44.33	30.90	45.35	38.13
IP 6104	48.48	67.90	58.19	27.62	52.02	39.82	38.05	59.96	49.00
IP 6110	42.52	48.62	45.57	52.58	50.50	51.54	47.55	49.56	48.55
IP 13150	33.75	54.10	43.93	35.90	31.65	33.78	34.83	42.88	38.85
IP 19612	38.27	66.23	52.25	41.58	53.20	47.39	39.93	59.72	49.82
IP 19586 B3	48.35	58.45	53.40	59.85	50.35	55.10	54.10	54.40	54.25
IP 22269	58.68	66.50	62.59	61.68	53.77	57.73	60.18	60.13	60.16
Sudan Pop I	41.88	48.98	45.43	46.12	45.90	46.01	44.00	47.44	45.72
Sudan Pop III	37.62	34.83	36.23	74.50	66.45	70.48	56.06	50.64	53.35
ICMV155 original	32.68	25.07	28.88	39.68	65.42	52.55	36.18	45.24	40.71
ICMS 7704	41.73	56.60	49.17	19.75	39.25	29.50	30.74	47.93	39.33
Mean	41.13	51.15	46.14	44.78	51.26	48.02	42.96	51.20	47.08

Statistical Parameters

Source of Variation	df	F-test	LSD (5%)
Replication	2	-	-
Year	1	NS	-
Varieties	10	NS	-
Water type	1	*	6.58
Year*Varieties	10	*	21.83
Year*Water type	1	NS	-
Varieties*Water type	10	NS	-
Year*Varieties*Water type	10	NS	-
Error	86		
Total	131		

Table 4. Means of dry matter yield (t/ha) of eleven pearl millet genotypes in two summer seasons under fresh (FW) and treated wastewater (TW) irrigation conditions

Genotypes	Summer 2012			Summer 2013			Mean		
	FW	TW	Mean	FW	TW	Mean	FW	TW	Mean
MC94C2	9.41	12.91	11.16	6.72	12.40	9.56	8.06	12.66	10.36
IP 6104	16.61	24.71	20.66	7.46	11.88	9.67	12.03	18.30	15.16
IP 6110	15.98	19.44	17.71	11.47	10.40	10.94	13.72	14.92	14.32
IP 13150	11.06	20.67	15.86	7.56	7.56	7.56	9.31	14.11	11.71
IP 19612	15.74	26.82	21.28	10.16	12.49	11.33	12.95	19.65	16.30
IP 19586 B3	19.28	22.25	20.77	15.92	12.48	14.20	17.60	17.37	17.48
IP 22269	25.48	28.42	26.95	16.16	13.66	14.91	20.82	21.04	20.93
Sudan Pop I	14.50	19.27	16.89	8.90	14.10	11.50	11.70	16.69	14.19
Sudan Pop III	12.64	14.39	13.51	17.57	16.64	17.11	15.11	15.51	15.31
ICMV155 original	15.80	8.48	12.14	10.55	14.06	12.30	13.17	11.27	12.22
ICMS 7704	17.07	20.71	18.89	5.20	10.94	8.07	11.14	15.83	13.48
Mean	15.78	19.82		10.70	12.42		13.24	16.12	

Statistical Parameters

Source of Variation	df	F-test	LSD (5%)
Replication	2	-	-
Year	1	**	2.21
Varieties	10	*	5.18
Water type	1	*	2.21
Year*Varieties	10	NS	-
Year*Water type	1	NS	-
Varieties*Water type	10	NS	-
Year*Varieties*Water type	10	NS	-
Error	86		
Total	131		

Table 5. Means of concentrations ($\mu\text{g}/\text{kg}$) of major elements (N, P and K) under fresh water and treated wastewater irrigation conditions over two experimental years

Element	Unit	Water type					
		Treated wastewater			Fresh water		
		0-15(cm)	15-30(cm)	Average	0-15(cm)	15-30(cm)	Average
Before planting							
N	$\mu\text{g}/\text{kg}$	313.0	220.0	266.5	214.0	205.0	209.5
P	mg/kg	60.1	42.9	51.5	79.3	627.0	353.2
K	mg/kg	120.0	40.0	80.0	80.0	60.0	70.0
After harvest							
N	$\mu\text{g}/\text{kg}$	324.0	302.0	313.0	313.0	280.0	296.5
P	mg/kg	49.6	87.4	68.5	50.2	70.2	60.2
K	mg/kg	40.0	60.0	50.0	40.0	50.0	45.0

Table 6. Means of concentrations (mg/kg) of micro- and heavy elements in soil under fresh water and treated wastewater conditions in two experimental years, 2012 and 2013

Elements		Mo	Pb	Cu	Cr	Mn	Ni	Zn							
2012	Fresh water	0-15 cm	12.43	3.90	4.84	0.50	32.71	13.29	34.29						
		15-30 cm	12.53	4.59	4.03	0.88	15.22	8.47	18.68						
	Treated wastewater	0-15 cm	13.10	3.54	3.41	0.78	16.91	10.23	16.35						
		15-30 cm	13.25	4.80	3.97	1.08	18.40	7.51	21.04						
2013	Fresh water	0-15 cm	7.33	19.12	18.24	0.75	185.41	36.29	47.80						
		15-30 cm	20.49	8.25	12.31	0.48	85.66	23.18	18.13						
	Treated wastewater	0-15 cm	13.14	12.74	17.04	0.65	121.39	29.18	24.75						
		15-30 cm	7.57	11.48	18.53	0.65	123.86	29.47	26.46						
Statistical parameters		F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)
Year		NS	-	**	2.49	**	3.35	*	0.17	**	45.32	NS	-	**	4.90
Water type		NS	-	NS	-	NS	-	NS	-	NS	-	NS	-	**	4.90
Depth		*	1.89	*	2.49	NS	-	NS	-	NS	-	NS	-	**	4.90
Year*WT		*	2.67	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-
Year*Depth		NS	-	**	3.52	NS	-	**	0.24	NS	-	NS	-	NS	-
WT*Depth		**	2.67	*	3.52	NS	-	NS	-	NS	-	NS	-	*	6.93
Year*WT*Depth		**	3.78	NS	-	NS	-	NS	-	NS	-	NS	-	NS	-
CV (5%)			17.3				37.2		26.4		69.1		32.7		21.6

Table 7. Means of concentrations (mg/kg) of micro- and heavy elements in plant samples under fresh water and treated wastewater conditions in two experimental years, 2012 and 2013

Year	Water type	Mo(ppm)	Pb(ppm)	Cu(ppm)	Cr(ppm)	Mn(ppm)	Ni(ppm)	Zn(ppm)
2012	Fresh water	1.48	0.34	2.63	1.81	12.71	1.39	66.79
	Treated wastewater	3.65	0.34	2.50	1.80	19.00	1.20	28.95
2013	Fresh water	0.71	0.97	2.08	4.49	20.35	3.12	279.33
	Treated wastewater	9.08	0.17	2.70	2.05	25.19	1.42	215.80

Statistical Parameters	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)	F-test	LSD (5%)
Year	NS	-	NS	-	NS	-	**	0.57	NS	-	*	0.93	**	66.4
Water type	NS	-	*	0.36	NS	-	**	0.57	NS	-	*	0.93	NS	-
Year*WT	NS	-	*	0.51	NS	-	**	0.80	NS	-	NS	-	NS	-
CV %		181.6		55.8		33.3		15.9		86.5		36.9		31.8