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Effects of irrigation water qualities on biomass and sugar contents of sugar beet and sweet sorghum cultivars

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Abstract: *An experiment involving four qualities of irrigation water, two sugar beet and three sweet sorghum cultivars was conducted in a split plot design with four replications at Rudasht Drainage and Reclamation Experiment Station in 1999. The results showed salinity of water has an adverse effect on sugar beet and sweet sorghum biomass. Sweet sorghum cultivar SSV108 had the lowest biomass under all qualities of irrigation water. Sweet sorghum cultivar Rio had the maximum biomass with water qualities of 2, 5, and 8 dS m.$^{-1}$. Sugar beet cultivar 7233 had the maximum biomass with 11 dS m^{-1}. The effect of irrigation water quality was not significant for sugar characteristics such as brix, pol and purity. However, responses of cultivars on the above parameters were significant and sugar beet cultivars had higher brix, pol and purity and lower invert sugar and starch than sweet sorghum cultivars. In conclusion, sweet sorghum cultivars are not recommended to be irrigated with saline water of more than 8 dS m^{-1} for sugar production. Under such condition, they may be suitable to be grown for forage purposes.*

Key words: *Sweet sorghum, Sugar beet, Water quality, Sugar contents*

Introduction

The source of suitable water for agriculture is declining, as a result water is used which was considered unsuitable for agriculture. In dry and semi-dry regions good quality irrigation water is scare and drainage water is used to meet crop water requirements. The use of drainage water for irrigation to complement the available fresh water to satisfy the needs of crops during drought periods is of prime interest for many regions in the world. (Letey *et al.*, 1985; Rhoades, 1989; Rhoades *et al.*, 1989; Minhas *et al.,* 1990; Katerji *et al.*, 1997). According to Chandra *et al.* (1997) blending is mixing of poor quality drainage water with good quality irrigation water provided that the blended water is sufficiently low in total salinity. This is the most economic and environmetally acceptable means of disposing drainage water. It is important to know the effects of salinity of water on soil and plants. Chandra *et al.* (1997) mentioned that drainage water can be used to supplement irrigation water. However, the quality of the drainage water determines which crops can be irrigated. Poor quality water requires selection of crop with appropriate salt tolerances. Crops differ greatly in their reponse to salinity. The most distinct sign of injury from salinity is reduced crop growth and loss of yield. Allison *et al.* (1969) reported that one of the methods to determine the tolerance of plants to saline water is to irrigate them with such water following their establishment. According to Francois and Goodin (1972) and Mccree (1987), sugar beet is tolerant to salinity except at the germination stage. Nasir *et al.* (1990) reported that tolerance of sorghum to salinity is moderate. Crops can tolerate salinity up to certain levels without a measurable loss in yield (salinity threshold). The more salt tolerant the crop, the higher the treshold level. At salinity levels greater than treshold, crop yield reduces linearly as salinity increases. Ayars and Schoneman (2005) used saline water from drainge in conjunction with good quality water. They found that wheat yields were reduced as a result of using the saline water while cotton and sugar beet were unaffected. Moreno *et al.* (2001) evaluated the effects of irrigation with high and moderately saline water on growth and yield of cotton and sugar beet. They found that yields of beet and sugar were significantly higher in plots irrigated with saline water than good quality water. Al-Tahir *et al.* (1997) irrigated barley with three water quality treatments and found that barley grain and straw yields were significantly decreased under the use of drainage water. These yields were not significantly different between mixed irrigation water and fresh canal irrigation water. They concluded that mixed water could be another alternative for irrigation. Sunseri *et al.* (1998) compared two sweet sorghum commercial varieties with sweet sorghum lines which were selected in semiarid area. They tested these cultivars and lines at three levels of soil salinity and found lines selected in the semiarid area are more tolerant to soil salinity.

Materials and Methods

The experiment was conducted at Rudasht Drainage and Reclamation Experiment Station in 1999. Four quality of irrigation water: 2, 5, 8 and 11 dS m^{-1} and two sugar beet cultivars, 7233 and 9597 and three sweet sorghum cultivars, Rio, SSV-108 and IS 2325, were assessed in a split plot design with three replications. The quality of irrigation water was assigned to main plots and the cultivars to sub plots. The plots were 40 m^2, 1.5 meter apart to prevent side effects.The area was plowed and

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Table - 1: Sum of squares for four water qualities, two sugar beet cultivars and three sweet sorghum cultivars for characteristics measured

Source of Variance	df	Biomass	Weight				
			Total dry	Fresh forage	Dry forage	Fresh carbohydrate storage organ	Dry carbohydrate storage organ
Block	2	26495	30484	18139	3618	13483	5754
Water quality	3	727133787**	88495198**	95926983**	8068121**	305902429**	43350064**
Error(a)	6	54169	8779	96957	8324	95357	16797
Cultivar	4	572268977**	32806615**	105996989**	1991644**	534999816**	19033467**
Water quality x Cultivar	12	52517872**	6467958**	2947432**	746838**	41673390**	3438551**
Error(b)	32	37791	12981	32456	13915	59242	14346

** Significant at 1 % level, df = degree of freedom

Table - 2: Mean comparisons among four water qualities for characteristics measured (kg/ha)

Water quality dS m^{-1}	Biomass	Weight				
		Total dry	Fresh forage	Dry forage	Fresh carbohydrate storage organ	Dry carbohydrate storage organ
2	64435^{a}	14008^{a}	15822^{a}	3105^{a}	48607^{a}	10903^{a}
5	58711^{b}	10996^{b}	14376^{b}	2209^{b}	44335^{b}	8914^{b}
8	52673^{c}	9549^{c}	11605^{c}	1921^{c}	41068^{c}	7629^{c}
11	48359^{d}	8740^{d}	10282^{d}	1692^{d}	38077^{d}	7047^{d}

1- Means with the same letters are not significantly different at 5% level, using LSD

Table - 3: Group mean comparison between sugar beet and sweet sorghum for biomass and carbohydrate content fresh weigh (kg/ha) for different water qualities

Water quality dS m^{-1}	Biomass			Fresh carbohydrate storage organ weight		
	Sugar beet	Sweet sorghum	Difference	Sugar beet	Sweet sorghum	Differences
2	60607	66987	6380**	41870	53097	11227**
5	57163	58899	1736**	39405	46651	7546**
8	54970	51143	3817**	40127	41694	1567**
11	51645	46148	5477**	38469	37816	653**

** Significant at 1% level

Table - 4: Mean comparisons among four water qualities for characteristics measured (kg/ha)

Cultivars	Biomass	Total dry weight	Fresh forage weight	Dry forage weight	Carbohydrate storage organ fresh weight	Carbohydrate storage organ dry weight
7233	57000^{b}	11360^{b}	16476^{a}	2452^{b}	40555^{c}	8908^{b}
9597	55744^{d}	10871^{c}	15861^{b}	2226^{bc}	39883^{d}	8645^{c}
Rio	65307^{a}	12930^{a}	11874^{c}	2705^{a}	53423^{a}	10225^{a}
SSV 108	45839^{e}	8478^{e}	9828^{e}	1665^{d}	36011^{e}	6963^{e}
IS2325	56293^{c}	10502^{d}	11066^{d}	2127^{c}	45227^{b}	8375^{d}

Mean with the same letters are not significantly different at 5% level, using LSD

disked and 100 kg of urea, 300 kg ammonium phosphate and 250 kg per hectare of potassium sulphate were distributed and disked into the soil. Two hundred kg per hectare of urea was side dressed 30 days after planting. Sugar beet and sweet sorghum seeds were planted by hand and irrigated with water from river with salinity of 1.6 dS m^{-1}. At 3 to 5 leaf stage, the sugar beet and sweet sorghum plants were thinned to 10 cm spacing respectively.

Plots received water from river until sugar beet plants had 8 leaves and sweet sorghum plants 4 leaves. Then the plots received irrigation water from different water qualities according to pan class A. To prepare 5,8 and 11 dS m^{-1}, the water from river and drainage water with salinity of 20 dS m^{-1} were mixed to get the desired salinity. Rhoades *et al.* (1992) classified 1.6 dS m^{-1} and 20 dS m^{-1} as irrigation water and secondary drainage water and gound water,

Table - 5: Group mean comparison between sugar beet and sweet sorghum for the characteristics measured

Characteristics (kg/ha)	Sugar beet	Sweet sorghum	Differences
Biomass	56387	55813	574**
Total dry weight	11115	10636	479**
Fresh forage weight	16168	10923	5245**
Dry forage weight	2339	2166	173**
Carbohydrate storage organ fresh weight	40219	44890	4671**
Carbohydrate storage organ dry weight	8777	8521	256**

** Significant at 1% level

Results and Discussion

Biomass - Analysis of variance for biomass, total dry matter, fresh and dry forage matter, fresh and dry weight of carbohydrate storage organ of sweet sorghum, sugar beet and cultivars are presented in Table 1. The effect of irrgiation water quality, cultivar and their interactions on the above measurements were significant at 1 percent level. Mean comparisons for the above measurements regarding different irrigation water qualities are presented in Table 2. As irrigation water quality decreased, all the above measured characteristices decreased. They were highest at 2 dS m^{-1} and lowest at 11 dS m^{-1}. Ayars and Schoneman (2005) used saline water from drainge in conjunction with good quality water. They found that wheat yields were reduced as a result of using the saline water while the cotton and sugar beet were unaffected. Moreno *et al.* (2001) evaluated the effects of irrigation with high and moderately saline water on growth and yield of cotton and sugar beet. They found that yields of beet and sugar were significantly higher in plots irrigated with saline water than good quality water. They irrigated one subplot with fresh water (1.7 dS m^{-1}) during the whole season, while in the other subplot two of the irrigations were with moderately saline water (5.9 - 7.0 dS m^{-1}). Al-Tahir *et al.* (1997) irrigated barley with three water quality treatments and found that barley grain and straw yields were significantly decreased under the use of drainage water. These yields were not significantly different between mixed irrigation water and fresh canal irrigation water. Group mean comparisons between sugar beet and sweet sorghum cultivars for biomass and carbohydrate storage organs fresh weigtht for 2, 5, 8 and 11 dS m^{-1} are presneted in Table 3. For water quality of 2 dS m^{-1} and 5 dS m^{-1} sweet sorghum cultivars had significantly higher biomass and carbohydrate storage organs than sugar beet cultivars. At water quality of 8 dS m^{-1}, biomass of sugar beet cultivars were higher than sweet sorghum cultivars, but their carbohydrate storage organs fresh weight were lower than sweet sorghum cultivars. At 11 dS m^{-1}, both biomass and carbohydrate storage organs fresh weight of sugar beet cultivars were higher than that of sweet sorghum cultivars. Sweet sorghum is a medium salt tolerant plant and so it is a suitable crop with irrigation water quality up to 8 dS m^{-1}. Sugar beet is a high salt tolerant plant and at irrigation water quality of 11 dS m^{-1}, is better adapted to salty

Table - 6: Sum of squares for four water qualities, two sugar beet cultivars and three sweet sorghum cultivars for characteristics measured

Source of variance	df	Brix	Pol	Purity	Invert sugars	Starch
Block	2	1.31	7.89	116.72	0.14	11960
Water quality	3	1.42	2.49	61.23	0.13*	194170**
Error (a)	6	9.21	4.81	148.25	0.05	14787
Cultivar	4	176.16**	387.78**	2916.48**	26.02**	24352
Water quality x Cultivar	12	6.97	8.37	97.13	0.06	38359**
Error (b)	32	8.49	6.66	90.91	0.06	12524

** , * Significant at 1 and 5 % level respectively, df = degree of freedom

Table - 7: Mean comparisons among four water qualities for invert sugar and starch

Water quality dS m^{-1}	Invert sugars %	starch ug/ml
2	1.58[a]	704.27[a]
5	1.80[ab]	650.27[a]
8	1.64a[b]	608.67[a]
11	1.66[b]	440.73[b]

1- Means with the same letters are not significantly different at 5% level, using LSD

respectively. Plants were harvested when sweet sorghum kernels were at hard dough stage and sugar beet leaves were nearly dried. Biomass for sugar beet was considered as the weight of the tuber (carbohydrate storage organ) and leaves (as forage) and for sweet sorghum the weight of stripped stalk (carbohydrate storage organ) and leaves and panicles (as forage). Following harvesting, each part of plants was weighed and dried at 80 degree centigrade for 48 hr and weighed again. A sample of sugar beet tuber and sweet sorghum stalk were harvested for chemical analysis. Brix value, sucrose content and purity of sugar beet and sweet sorghum stalk were determined according to Vukov (1977) and Varma (1988), respectively and Invert sugar of sugar beet according to Vukov (1977) and that of sweet sorghum according to method by Lane-Eyon (1970). Starch content was measured by ICC method (1994).

Table - 8: Mean comparisons[1] between sugar beet and sweet sorghum cultivars for characteristics measured

Cultivars	Birx (%)	Pol (%)	Purity (%)	Invert sugar (%)
Sugar beet 7233	25.30[a]	20.58[a]	81.37[a]	0.05[a]
Sugar beet 9597	25.28[a]	18.62[a]	74.90[a]	0.06[a]
Sweet sorghum Rio	17.61[b]	9.59[b]	52.77[b]	2.79[b]
Sweet sorghum SSV108	19.08[b]	9.19[b]	47.83[b]	2.80[b]
Sweet sorghum IS23251	8.39[b]	9.12[b]	49.21[b]	2.64[b]

Means with the same letters are not significantly different at 5% level, using LSD

Table -9: Group mean comparison between sugar beet and sweet sorghum for the characteristics measured

Characteristics	Sugar beet	Sweet sorghum	Differences
Brix	25.29	18.36	6.39**
Pol	19.60	9.30	10.30**
Purity	78.13	503.7	27.86**
Invert sugar	0.55	2.74	2.68**
Starch	558.39	629.44	71.05*

** , * Significant at 1 and 5 % level respectively

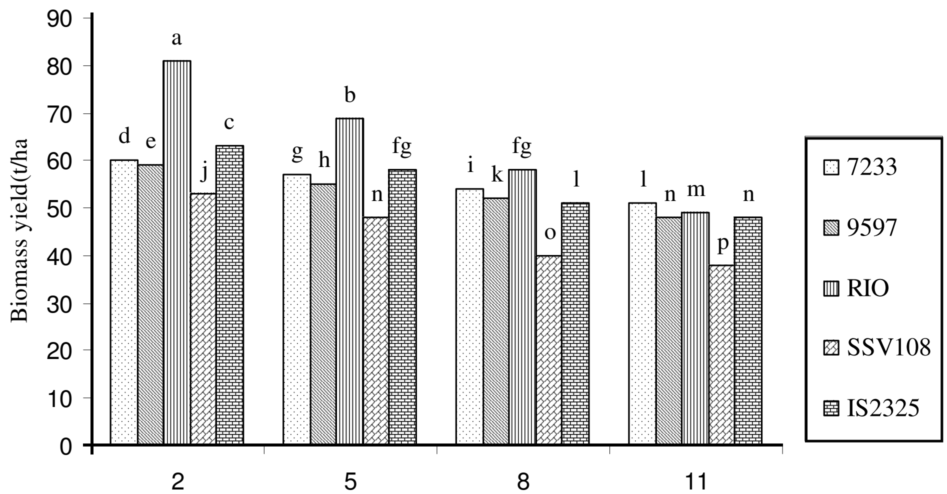

Fig. 1: Effects of irrigation water qualities on biomass of sweet sorghum and sugar beet cultivars

irrigation water than sweet sorghum. Mean comparisons for biomass, total dry weight, fresh and dry forage weights and fresh and dry carbohydrate storage organs of sweet sorghum and sugar beet cultivars are presented in Table 4. These measurements except fresh forage weight for both sweet sorghum and sugar beet cultivars were highest for cv Rio and lowest for SSV108. Regarding sugar beet cultivars these measurements were higher for cv 7233 than cv 9597. Group mean comparisons between sweet sorghum and sugar beet cultivars for biomass, total dry weight, fresh and dry forage weight, fresh and dry carbohydrate storage organ are presented in Table 5. The results showed except carbohydrate storage organ fresh weight, sugar beet cultivars had higher biomass, total dry weight, fresh and dry forage weights and dry carbohydrate storage organs than sweet sorghum cultivars. The interaction between irrigation water quality and sweet sorghum and sugar beet cultivars for biomass is shown in Fig. 1. Except for irrigation water quality of 11 dS m^{-1} sweet sorghum Rio had higher biomass than other sweet sorghum and sugar beet cultivars. Genotypes respond differently to the quality of irrigation water. Sunseri *et al.* (1998) concluded that lines selected in the semi arid area are more tolerant to soil salinity since they showed a higher Na/K ratio. In this experiment Na/K ratio of sweet sorghum cultivars were not measured but may be Na/K ratio of cv Rio was higher than SSV 108 and IS2325. cv Rio had higher biomass than sugar beet cultivars at 2, 5 and 8 dS m^{-1} but not at 11 dS m^{-1}. Sweet sorghum is a C4 plant and is better adapted to hot and dry climatic conditions than sugar beet which is a C3 plant as Jensen (1980) reported sorghum and sugar beet are medium and high salt tolerance crop respectively. Under low to medium irrigation water quality, sorghum due to its adaptibiliy to climatic condition

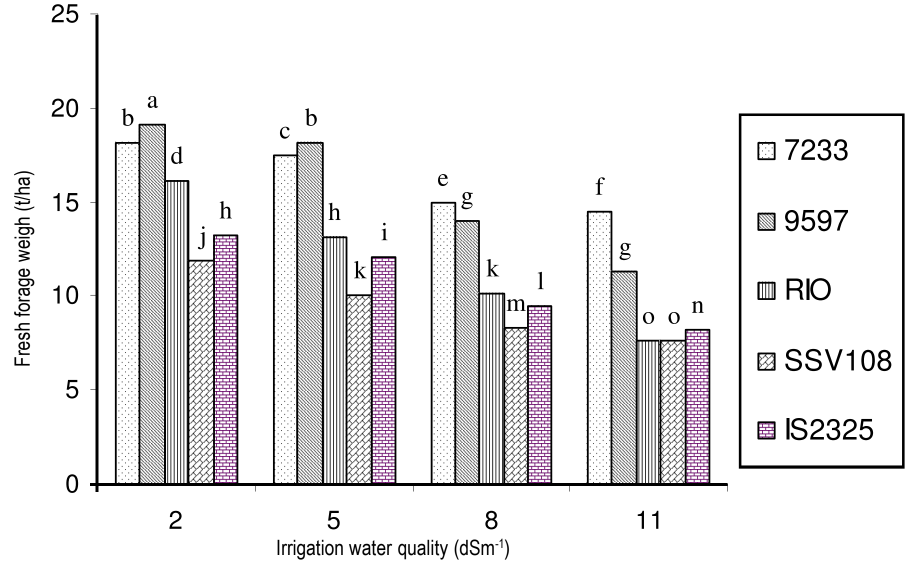

Fig. 2: Effects of irrigation water qualities on fresh forage weight of sweet sorghum and sugar beet cultivars

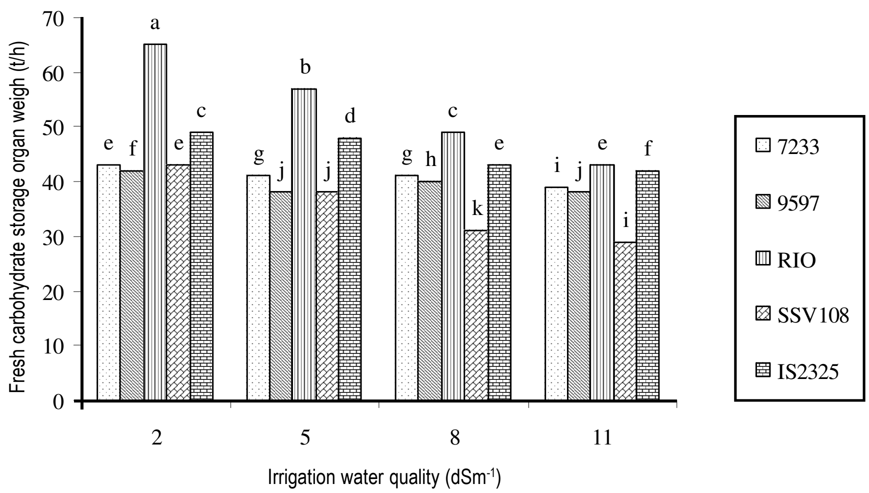

Fig. 3: Effects of irrigation water qualities on fresh carbohydrate storage organ weight of sweet sorghum and sugar beet cultivars

has higher biomass than sugat beet which is not adapted to these conditions. However under high irrigation water qulity (11 dS m^{-1}), suger beet is more adpated to salinity than sorghum and therefore its biomass was higher than sorghum. In all irrigation water qualities cv 7325 had higher biomass than cv 9597, cv 7325 is polygerm while cv 9597 is monogerm. It seems ploygerm cultivars are more salt tolerant than monogerm. As the quality of irrigation water decrease, biomass of both sweet sorghum and sugar beet cultivars decreased. Katerji *et al.* (1997) reported a decrease of leaf area of sugar beet when salinity of irrigation water increased. The interactions between irrigation water qualities and fresh forage yield of sweet sorghum and sugar beet cultivars are presented in Fig. 2. In all irrigation water qualities fresh forage yield of sweet sorghum cultivars were lower than sugar beet cultivars but fresh forage yield of sweet sorghum contains leaves and panicles are more valuable than fresh forage yield of sugar beet which only contains leaves. Among sweet sorghum cultivars in water quality of 2 , 5 and 8 dS m^{-1} fresh forage yield of cv Rio was higher than the other cultivars. Sugar beet cv 9597 is monogrem and had higher fresh forage yield than polygerm 7233 in irrigation water quality of 2 and 5 dS m^{-1}. As irrigation water quality decreased, fresh forage yield of polygerm 7233 was higher than monogerm 9597 indicating polygerm sugar beet cultivars are more tolerate to salt than monogerm types. Fresh carbohydrate storage organs of sweet sorghum and sugar beet cultivars for different irrigation water qualities are presented in Fig. 3. Among sweet sorghum and sugar beet cultivars, cv Rio in all irrigation water qualities had the highest fresh carbohydrate storage organ weight. Following cv Rio, IS2325 had higher fresh carbohydrate storage organ weight than sweet sorghum cv SSV 108 and sugar beet cultivars. Fresh carbohydrate storage organ weight of sugar beet cv 7233 was higher than cv 9597 for all irrgiation water qualities.

Carbohydrate content- Analysis of variance for brix value, pol, purity, invert sugar and starch are presented in Table 6. The effect of water quality on starch and invert sugars were significant at 1% and 5% respectively. Mean comparisons among four irrigation water qualities on invert sugars and starch (Table 7) indicating invert sugars were signifiantly lower at 2 dS m^{-1} than 11 dS m^{-1}, while starch content was higher at 2 dS m^{-1} than 11 dS m^{-1}. It seems salts in the irrigation water hydrolysis some of the starch to invert sugar. The effects of sugar beet and sweet sorghum cultivars on brix, pol, purity, invert sugars were significant at 1 percent level (Table 6). Sugar beet cultivars had higher brix, pol and purity but lower invert sugars than sorghum cultivars (Table 8). Group mean comparisons (Table 9) indicated sugar beet cultivars had higher desirable sugar characteristics such as brix, pol and purity than sweet sorghum and sweet sorghum cultivars had higher undesirable sugar characteristics such invert sugars and starch than sugar beet cultivars.

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