Forages Growing in Saline Drainage Water Re-use Systems on the Westside San Joaquin Valley of California: Water Use, Productivity and Nutritional Value

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1 INTRODUCTION

Reuse of saline drainage water (DW) is a management option that has been proposed for the Westside San Joaquin Valley (SJV) in order to reduce both the area affected by shallow water tables and the volume of drainage effluent requiring disposal (San Joaquin Valley Drainage Implementation Program, 2000). Objectives of the approach are to manage salt and DW on the farm (IFDM), or regional scale, and at the same time to minimize environmental impacts such as salt loading into rivers and risks to wildlife from selenium or other trace elements present in the DW. Forage production is particularly appealing for DW re-use systems because of the very high degree of salt tolerance demonstrated by some of the forages tested (Grattan et al., 2004), and a growing local demand for forage material due to the rapid influx of dairies into the SJV in recent years. Cultivation of salt-tolerant forages would not only increase forage supplies, but it can play a key role in DW management (Qadir & Oster, 2004).

Forage selection for DW reuse systems should be based on their demonstrated ability to maintain productivity over the long term in soils irrigated with saline-sodic DW. Depending on the characteristics of the DW, these soils are likely to experience sodium-induced clay dispersion and have reduced infiltration and low permeability to water and oxygen (Oster, 1994). Several salt tolerant forages performed well under DW irrigation in a sand tank study at the USDA Salinity Laboratory in Riverside, CA (Grattan et al., 2004). Some of these forages were also evaluated for two years in large field plots at Red Rock Ranch (RRR) in Five Points, California, in soils that had received DW irrigation for four to five years and were in very poor physical condition. Results of our field evaluations will be presented in this oral presentation. Due to large degree of variation in soil salinity amongst the forage fields at RRR, a greenhouse study was also conducted to evaluate the more promising forages in a field soil: sand mix under uniform and controlled soil conditions. Results of this greenhouse study will be presented in a poster (Suyama et al.).

The objectives of the research are to: 1) evaluate the suitability of these forages for long-term irrigation with saline-sodic DW, and 2) to assess their water use, productivity, nutritional value, and safety for feeding to animals after multiple years of DW irrigation.

2 MATERIALS & METHODS

The salt tolerant forages growing in the field at Red Rock Ranch include:

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Tall wheatgrass (TWG: *Thinopyrum ponticum**, var.'*Jose*') *formerly, *Agropyron elongatum*
Creeping wildrye (CWR: *Leymus triticoides* var. *'Rio'*),
Tall fescue (TF) (*Festuca arundinacea*, var. '*Alta*'),
Alkali sacaton (AS) (*Sporobolus airoides* var.*'solado'*),
Puccinellia (Pucc.) (*Puccinellia ciliata*).
Paspalum** (*Paspalum vaginatum* var. '*Southeast'*) **only growing in lysimeters

With the exception of one CWR field, most forages were established from seed and were irrigated with freshwater for the first year. Fields ranged in size from 0.5–21 ha, as they were planted by the grower. At the time of sampling these forage stands were in their fourth and fifth year of irrigation with saline-sodic DW containing high levels of boron and selenium (EC 8–13 dS/m, SAR 13–42, B 15–25 mg/L, Se 0.45–1.3 mg/L). The cracking clay loam soils showed evidence of salt accumulation and clay dispersion resulting from the sodic DW. These forages were not fertilized due to the high N content of the DW (36–85 mg/L NO_3-N).

Productivity was measured using a rotational cutting system in which the entire forage plot was initially cut to 15 cm and then cuts were taken in 1 m^2 sub-plots when the stand reached 30 cm, 45 cm, and its final height prior to heading. Organic forage quality was assessed as metabolizable energy (ME) using an *in vitro* rumen fluid gas test that measured gas evolution (Robinson & Getachew, 2002). Crude protein (CP), neutral detergent fiber (NDF), ash, and mineral analyses (Ca, Mg, P, K, S, Na, Cl, NO_3, B, Se, Mo) utilized standard lab procedures.

Water use (ET) was measured using sand-filled, drainage lysimeters (1.3 m x 1.3 m). The DW used to irrigate the lysimeters averaged 11–13 dS m^{-1} EC, 20–25 mg L^{-1} B, and 0.9–1.3 mg L^{-1} Se). Tall fescue (*Festuca arundinaceae* var. '*Southeast*') irrigated with nonsaline water (< 2 dS m^{-1}) served as the nonsaline control. Replication was four. Data were compared to CIMIS ETo, a reference ET provided by local weather station data. Nutrients were added to the lysimeter tank waters (3 mM KNO_3, 0.5 mM KH_2PO_4, 20 uM Fe-DTPA). Tank waters were supplemented with KNO_3 when N levels dropped to 25% of starting levels and were changed midway during the season. Forages were trimmed during the season to maintain canopy heights similar to the surrounding vegetation.

3 RESULTS AND DISCUSSION

3.1 Water Use (ET)

From July to October 2004, average daily ET for tall wheatgrass (TWG) and creeping wildrye (CWR) was 5.71 and 5.93 mm day^{-1}, respectively, which was slightly lower than the reference ET of 6.08 mm day^{-1}. Paspalum, a grass having shorter stature, averaged 4.39 mm day^{-1} when irrigated with DW during this period.

Forage	Cumm. ET (Jul-Oct.)	Daily ET (Jul-Oct.)	Kc (Jul-Oct.)	Kc_{SR} (July)
TWG	680	5.71	0.94	0.99-1.11
CWR	706	5.93	0.98	.
Paspalum	522	4.39	0.72	.
Reference ET	723	6.08	.	.

Table 1. Cumulative and daily ET and crop coefficients (Kc) from lysimeter and surface renewal methods.

Crop coefficients (Kc's) for TWG and CWR averaged 0.94 and 0.98, respectively, for July to October 2004, whereas the Kc for Paspalum was 0.72. These Kc's were calculated from the lysimeter measurements (ETc/ETo). The Kc of 0.94 for TWG agreed well with Kc's of 0.99 and 1.11 for the same forage in July which were obtained using data from two surface renewal ET stations (Snyder et al., 1996) installed in the large field (21 ha) of TWG at RRR.

3.2 Productivity

Due to pre-existing spatial variability in soil properties, the large forage fields irrigated with saline DW at RRR had considerable differences in soil salinity. Creeping wildrye growing in DW-irrigated fields having salinities of 13.3–13.5 dS m^{-1} had the highest annual biomass production (10.0–13.8 MT ha^{-1}) in both years of measurement (Fig. 1). Tall wheatgrass growing in much more saline fields (ECe 17.5 and 20.3 dS/m) produced 5.9– 8.3 MT DM ha^{-1}. The very low yield (<3 MT / ha) of one tall wheatgrass stand was due to insufficient irrigation. Alkali sacaton and '*Alta*' tall fescue growing at soil salinities of 12 dS/m ECe had lower productivities (5.4–7.9 MT ha^{-1} and 3.9–5.1 MT ha^{-1}, respectively). The low biomass yield of tall fescue was probably due to the high soil salinity: at other locations this forage has grown well under irrigation with DW < 7 dS m^{-1} (C. Hurley, personal communication). Puccinellia accumulated an average of 5.55 MT ha^{-1} DM in a growing season which generally lasts only from November to early May.

The DW-irrigated forges had lower productivities than did salt tolerant alfalfa varieties (50:50 mix of '*salado'* and '*801S*') growing in an adjacent field (ECe= 5.23 dS/m) which produced an average of 17–21 MT ha^{-1} under freshwater irrigation (data not shown).

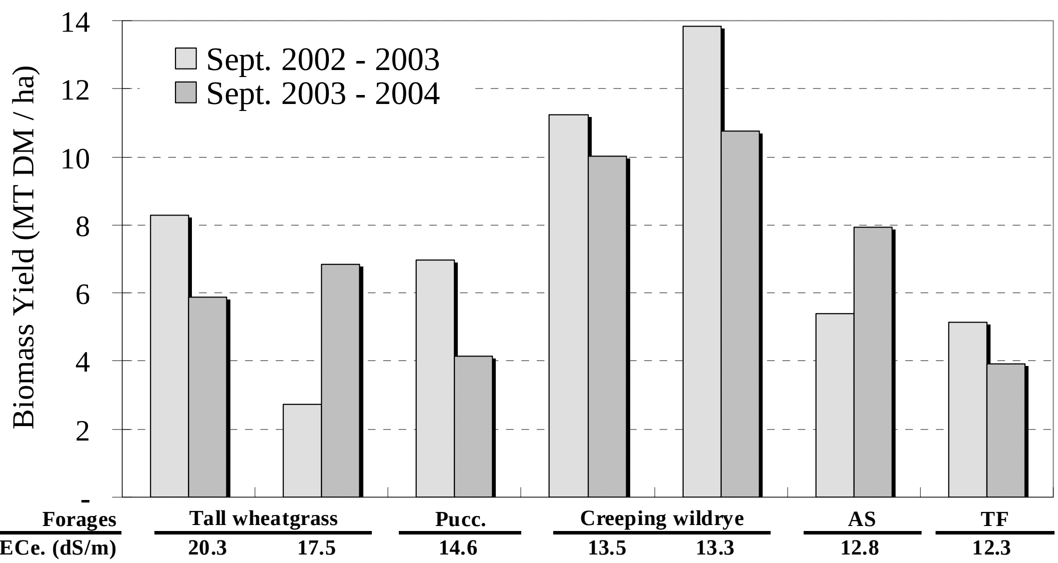

Fig. 1. Cumulative biomass production and soil salinity of forage fields (2002– 2004).

3.3 Forage Quality

Metabolizable energy (ME in MJ kg^{-1}) is a good indicator of forage quality because it is highly correlated to the growth rate of ruminants (Robinson & Getachew, 2002). Except for alkali sacaton (AS), the ME of the DW-irrigated forages was always 7– 10 MJ kg^{-1} DM (Table 2) which is acceptable quality for most ruminants. TWG and tall fescue (TF) forage had ME $\geq$ 9 MJ kg^{-1} which is an acceptable quality for animals requiring a high energy diet such as lactating dairy cows. CWR and Puccinellia forage had ME < 9 which is a quality more appropriate for non-lactating animals. In comparison, freshwater-irrigated alfalfa growing in moderately saline soil (5.2 dS/m) at RRR had the highest ME (9.6 MJ/kg). TF and Puccinellia had higher crude protein, and TF and TWG had NDF below 60% which is desirable. Ash levels of the DW-irrigated forages were 7– 10.8% and were not increased by DW irrigation.

Due to the high selenium (Se) concentration in the DW at RRR and the long period of DW irrigation, Se contents of the DW-irrigated forages reached as high as 8.4 mg kg^{-1} DM for CWR which is well above the maximum tolerable concentration (MTC) (NRC, 1989). Although Se supplementation is required in animal production in many areas of California, care would need to be taken when feeding this high Se forage to ruminants.

Forages	ECe (dS/m)	ME MJ/kg DM	CP	NDF	Ash	NO_3-N	Se	Mo	B	Ca	P	Mg	K	S	Na
				% DM			mg/kg DM					% DM			
Alf. *sal*	5.2	9.6	25	34	10.3	239	0.8	4.9	99	1.55	0.27	0.24	2.60	0.34	0.35
TF	12.3	9.1	18	53	10.8	163	**7.6**	3.8	1051	0.35	0.16	0.18	1.64	0.48	1.15
AS	12.8	7.0	13	71	8.7	50	**5.1**	2.1	327	0.49	0.10	0.18	1.96	0.44	0.15
CWR	13.3	7.8	14	64	7.9	50	**8.4**	1.4	305	0.33	0.12	0.13	1.95	0.36	0.28
"	13.5	7.9	16	63	8.3	130	**1.9**	1.4	174	0.31	0.17	0.10	2.49	0.21	0.14
Pucc.	14.6	8.6	18	61	8.5	100	**3.9**	0.8	58	0.27	0.20	0.12	2.34	0.28	0.60
TWG	17.5	9.1	15	57	9.9	110	**6.3**	1.7	418	0.21	0.18	0.11	1.72	0.29	0.78
"	20.3	8.7	10	60	7.0	50	**6.0**	1.3	557	0.25	0.11	0.14	1.41	0.38	1.04
Desirable / MTC		> 7	> 8	< 72		1000	> 2	> 5		0.2 - 0.3	0.15 - 0.19	> 0.4	> 3	> 0.4	

Table 2. Forage quality and mineral nutrient concentrations of DW-irrigated forages and freshwater-irrigated alfalfa. Desirable levels or maximum tolerable concentrations (MTC) of elements are shown in the bottom row.

4 CONCLUSIONS

Forages have been identified that maintain adequate biomass production and quality when grown in soils having poor physical conditions due to long term irrigation with saline-sodic DW. Even though cattle grazed on these forages at two locations (RRR and Westlake Farms (Kaffka et al., 2004)) showed no apparent growth or reproductive problems, the presence of selenium and molybdenum in the DW in some locations in the SJV will require that trace elements be monitored both in the forage and in the animals. Proper soil and water management will also be needed for sustainable forage production over the long term.

5 REFERENCES

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