

## Forage production using saline drainage water: assessing the selenium hazard for grazing beef cattle

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### Introduction

Salinity in soils or irrigation water affects over 1.86 million hectares of irrigated cropland in California, primarily on westside San Joaquin Valley (SJV) where over 207,000 hectares are also affected by shallow groundwater (< 3 m from the land surface) and poor drainage. Due to environmental hazards associated with selenium (Se) in shallow groundwater, research has been conducted since the late 1980's to utilize subsurface drainage systems for salinity and drainage control, while managing the drainage water (DW) to minimize impacts to wildlife. Re-use of DW for the irrigation of salt tolerant forages, halophytes, and oilseed crops is one strategy currently implemented by some farmers in the area. At Red Rock Ranch (RRR) where this research is conducted, the Integrated On-farm Drainage Management (IFDM) system is now growing canola for bio-diesel production and raising beef cattle using saline DW as the main water source. Our previous research demonstrated that forages such as tall wheatgrass and creeping wildrye had adequate water use (ET) and acceptable biomass production and forage quality (Suyama et al., 2007) under irrigation with this saline DW (EC<sub>w</sub> 8-12 dS/m, B 10 to 20 mg/L, and SAR 15 to 23). However, the accumulation of selenium to as high as 10 mg/kg (ppm) of dry matter (DM) in the forage raised concerns for their suitability as ruminant feeds. The current study was initiated to: 1) monitor accumulation of Se and other minerals in the blood and liver of beef heifers grazing DW-irrigated, tall wheatgrass and creeping wildrye, 2) evaluate heifer weight gains when grazing these forages, and 3) estimate acceptability and DM intake of DW-irrigated, tall wheatgrass and creeping wildrye to beef heifers. A supplemental study is underway to examine Se depletion once the heifers are removed from these high Se forages.

### Materials and methods

Red Rock Ranch is located near Five Points (CA, U.S.A). Most of the soil is mapped as a salinesodic Vertisol belonging to the 'Ciervo' series (<http://soils.usda.gov>). The two forages evaluated were 'Jose' tall wheatgrass (TWG) (*Thinopyrum ponticum* var. 'Jose'), formerly *Agropyron elongatum* and creeping wildrye (CWR) (*Leymus triticoides* var. 'Rio'). The TWG pasture was in its eighth year of irrigation with saline drainage water and had an average soil salinity of 20.7 dS/m EC<sub>e</sub>, boron = 32.1 mg/kg, and sodium adsorption ratio (SAR) = 47.4. The CWR pasture was in its fifth year of DW irrigation and had an average soil salinity of 15.7 dS/m EC<sub>e</sub>, boron = 27.7 mg/kg and SAR = 37.5. Total selenium averaged 3.3 and 1.9 mg/kg for the TWG and CWR pastures, respectfully, prior to beginning the study.

Twenty, approximately 6 month-old, Galvi Black Angus heifers purchased from a single herd were divided into four groups of five with each having a nearly equal total body weight. A nine-ha pasture of each forage was divided into four 76 x 260 m paddocks (i.e. A,B,C,D for each grass) which were rotationally grazed by two groups (north and south) of 5 heifers. The rotation period was two weeks for the first half of the season after which it was increased due to delays in obtaining irrigation water for the pastures. Initial body weight, blood, and liver samples were collected (by jugular puncture and biopsy, respectively) before the heifers entered the pastures on 21 May 2007. With the exception of an initial copper supplement (Copasure boluses 12.5 gram; Walco International, Inc., Westlake, TX), the cattle ate only the pasture forage. Blood samples were collected from the heifers every 45 days and body

weights were measured again in August. After 190 days of grazing (late November 2007), blood, liver, and muscle samples were collected again, along with final body weights. At this time, restricted amounts of forage were available so heifers grazing both grasses were supplemented with tall wheatgrass hay for the final month prior to removal from the pastures for finishing prior to slaughter.

Samples of both forages were collected from four 1 m<sup>2</sup> sub-plots in each paddock before and after the heifers entered to so as to determine DM availability. In addition, heifers were dosed with a slow release capsule of n-alkanes (C32 and C36; Captec, NZ) to estimate DMI during the final third of the study (Mayes et al., 1986). Pooled paddock samples were analyzed for minerals (Ca, Mg, P, S, NO<sub>3</sub>- N, Na, Cl, B, Zn, Mn, Fe, Cu, Mo, and Se) and organic forage quality was evaluated using a rumen fluid gas test to estimate metabolizable energy (ME; Getachew, 2004) and standard analytical procedures (AOAC, 2000) for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and organic matter analysis. Soil samples (0 - 45 cm) collected mid-way (August) and near the end of grazing (November), along with periodic samples of irrigation water, were analyzed for major and minor ions. Data sampled over time was analyzed as repeated measures utilizing the PROC MIXED (SAS, Release 8.2, 2001); otherwise a one way ANOVA model that included the effect of forage was utilized. Heifers were considered the experimental unit.

## Results and discussion

Soil salinity, sodicity, and boron concentrations were very high in these pastures (Table 1). Salinity was substantially higher in the TWG pasture—reflective of 8 years of DW irrigation versus 5 years for the CWR pasture— however, it has stabilized near 20 dS/m ECe for the 0 - 30 / 0 - 45 cm depth for the last few years. Current data for soil Se and Mo, the trace elements of concern relative to the health of the ruminants potentially grazing it, are not yet available.

**Table 1 Soil chemistry for the forage pastures (22 August 2007, 0 - 45 cm depth)**

Pasture	ECe <sup>†</sup> dS/m	pH	SAR <sup>††</sup>	Chloride (mg/kg)	Sulfate (mg/kg)	Boron (mg/kg)	Selenium (mg/kg)	Molybdenum (mg/kg)
Tall Wheatgrass	20.7 (1.3)	8.4 (0.02)	47.4 (2.9)	2685 (394)	9654 (396)	32.1 (1.9)	n.a.	n.a.
Creeping wildrye	15.7 (0.8)	8.4 (0.02)	37.5 (2.4)	1921 (155)	7203 (363)	27.7 (1.4)	n.a.	n.a.

<sup>†</sup> ECe= electrical conductivity of a saturated paste extract (measurement of salinity)

<sup>††</sup> SAR= sodium adsorption ratio. Measurement of sodicity

Forage DM availability was low in the pastures, particularly for TWG. The average height of the forage was 31.3 cm for TWG and 41.4 cm for CWR. The low DM availability during the grazing season was due in part to the high salinity of the pasture soils, but also due to low soil moisture as irrigation water supplies were limited in the second half of the season. The dry condition of the pastures for nearly half of the grazing period is also reflected in the high DM percentages of the forage, which averaged 44.2% for tall wheatgrass and 62.8% for creeping wildrye.

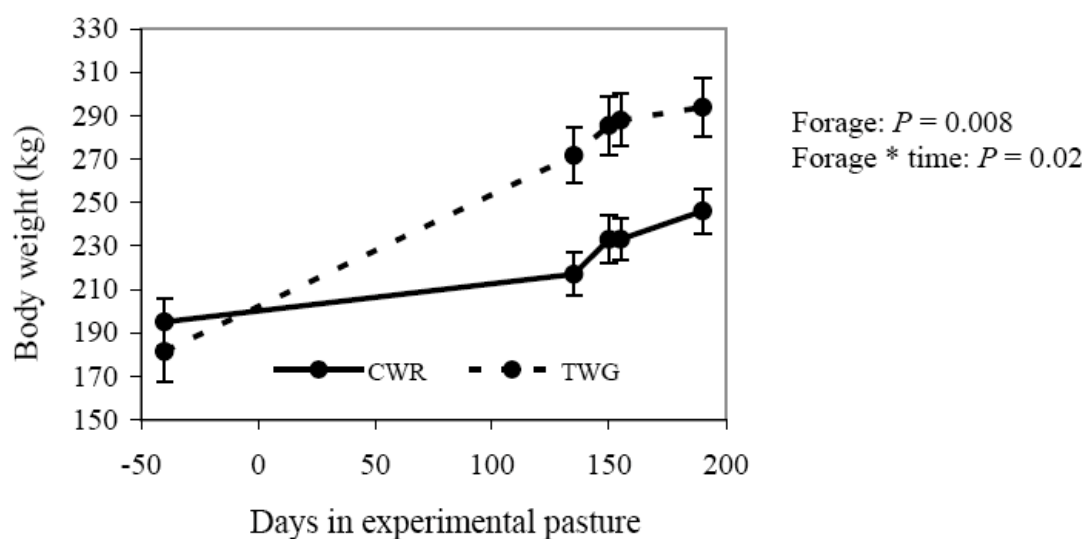
Forage composition for samples collected in late May is in Table 1. Similar to data collected earlier for these pastures (Suyama et al. 2007), TWG had higher forage quality (ME and CP) than CWR. These concentrations in the forage of 4.7 and 3.9 mg/kg DM for TWG and CWR, respectively, were well above the maximum tolerable concentration (MTC) of 2 mg Se/kg DM (NRC, 2000). The sulfur concentration of 5.8 g/kg DM for TWG was also above the MTC of 3 – 5 g/kg DM (NRC, 1996) to prevent toxic effects due to polienccephalomalacia (i.e., cerebrocortical necrosis) in cattle.

**Table 2 Forage mineral content and organic quality (DM basis) for samples taken 21 May, 2007**

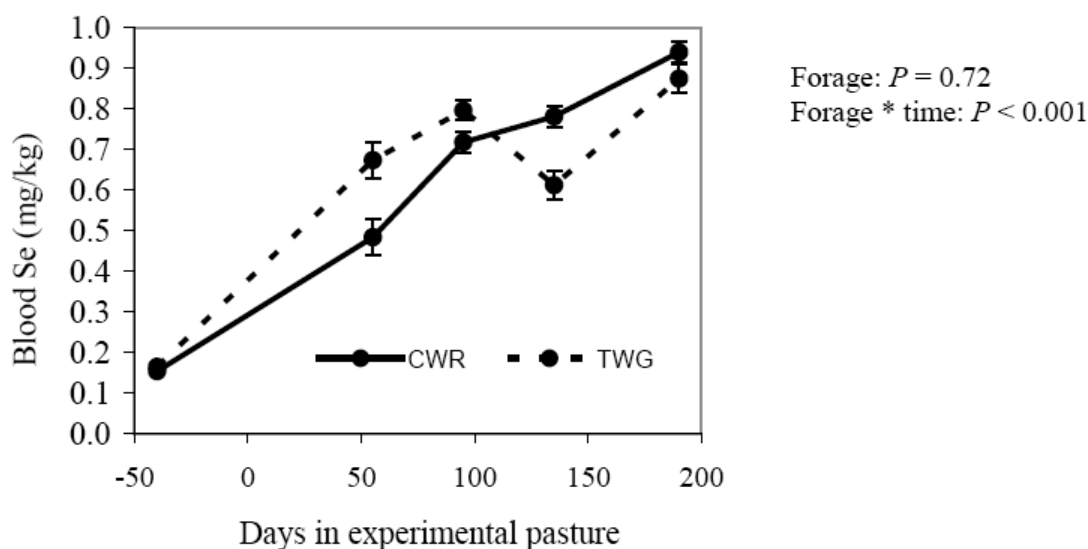
Forage	N % DM	Ca % DM	P % DM	S % DM	Na % DM	Cl % DM	B ppm	Cu ppm	NO <sub>3</sub> -N ppm	Mo ppm	Se ppm	ME <sup>†</sup> MJ/kg DM	CP % DM	NDF <sup>†</sup> % DM	Ash % DM
Tall Wheatgrass	1.9	0.28	0.15	0.58	1.42	1.85	304	5.9	81.3	2.2	4.7	8.0	12.2	n.a.	n.a.
Creeping wildrye	1.8	0.31	0.13	0.25	0.21	1.26	198	6.7	33.8	1.1	3.9	7.2	11.0	n.a.	n.a.

<sup>†</sup>ME = metabolizable energy; NDF = neutral detergent fiber

In spite of the relatively low dry matter availability and low metabolizable energy in the forage, the daily weight gains of the heifers were judged to be good, being  $0.59 \pm 0.07$  kg/day for TWG (n= 6) and  $0.27 \pm 0.07$  kg/day for CWR-grazed (n = 10) heifers. The heifers grazing tall wheatgrass, the higher quality forage, had higher weight gains ( $P < 0.01$ ) versus cattle grazing creeping wildrye, the lower quality forage (Fig. 1).



**Figure 1 Changes in body weight for black angus heifers grazing saline DW-irrigated forages in 2007**



**Figure 2 Selenium concentrations in total blood for black angus heifers grazing DW-irrigated forages, 2007**

Selenium concentrations in the blood of angus heifers (n=20) increased rapidly in response to grazing these DW-irrigated forages. Within 95 days of entering the pastures, blood Se increased ( $P < 0.01$ ) from below 0.2 mg/kg to above 0.70 mg/kg (Fig. 2). At the end of the study (195 days) heifers consuming either forage had blood Se near or above 0.90 mg/kg, far above the concentration deemed as safe (0.50 mg/kg). Similarly, Se concentrations in the liver

of the heifers increased from an average of less than 0.40 mg/kg to 2.08 or 3.9 mg/kg for heifers grazing tall wheatgrass and creeping wildrye, respectively (data not shown).

The heifer body weight gains observed during the study and the apparent absence of clinical signs of selenium toxicity are notable since the blood Se levels remained far above accepted 'safe' levels. Assays of selected animal tissues will be conducted after slaughter to better assess the potential hazard of these high Se forages to the health of grazing beef cattle.

### **Conclusions**

Preliminary data suggest that saline DW-irrigated forages that accumulate high levels of selenium may be safely used to graze feeder cattle which are usually grazed only one year prior to slaughter. More detailed research is underway to look for clinical evidence of selenium (or sulfur) toxicity which could limit their use in cattle-calf operation. In fact, should selenium levels be high in the meat from cattle grazing these forages, this could provide a value-added product given the interest in selenium as an antioxidant and cancer protectant in humans. The location where this research was conducted has some of the highest levels of native selenium in soils and drainage water, therefore it is likely that in other areas of the westside SJV, forages produced using saline DW would have much lower levels of selenium. They could, however, have DW high in other trace element, e.g. molybdenum, which could limit their use in animal production systems. Although high Se in forage presents the health risks for grazing cattle investigated in this study, high Se forage could also be valuable if processed into a feed supplement for ruminant animals in areas such as the eastside SJV of California where Se deficiency is more of a problem. The production of forage for animal production is only one of several valuable salt tolerant crops which can be grown using this "wastewater" as an irrigation water source. Due to the saline-sodic nature of this DW and the potential for degradation of soil physical properties, optimal soil and water management is needed to keep these DW re-use systems sustainable over the long term.

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