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Original Research Article

A Preliminary Report on the Influence of Various Saline Irrigation Waters on Nutritive Value upon Establishment of Alfalfa and Triticale as Representative Forages

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Abstract: Global population increases have expanded livestock industries and the demand for forage production. These factors have necessitated forage production with poor-quality irrigation water in semi-arid and arid regions. A greenhouse study evaluated the effect of poor-quality irrigation water on seedling growth to 90 days after planting alfalfa (*Medicago sativa*) and *triticale* [×*Triticosecale* Wittm. ex A. Camus (*Secale* × *Triticum*)], which were selected as representative forage crop species. Treatments were: fresh water (control; 0.7 dS m^{-1}), brackish groundwater (BGW; 4 dS m^{-1}), reverse osmosis concentrate (ROC; 8 dS m^{-1}; Ca dominant), and BGW plus sodium chloride (BGW+NaCl; 8 dS m^{-1}; Na dominant). Treatment influences on germination have been reported. This article reports the potential influence of those treatments during that 90-d period after which newly spring-seeded alfalfa would normally be harvested the first time and triticale would typically be ready to graze. Increasing salinity of the irrigation water had no effect on forage crude protein content, but it reduced acid detergent fiber and amylase-treated neutral detergent fiber (aNDF) (375, 310, 300, 319 g kg^{-1} aNDF for the control, BGW, ROC, and BGW+NaCl treatments, respectively; $P < 0.05$, SED = 15) and increased non-fiber carbohydrates. Further research at the field level and over a longer period for alfalfa is needed to validate the results of this preliminary study and to evaluate the influence of poor-quality water for irrigating these and other forage crop species.

Keywords: Alfalfa; Brackish groundwater; Forage nutritive value; Reverse osmosis concentrate; Salinity; Triticale.

INTRODUCTION

The availability and quality of irrigation water play an important role in producing high-quality forage crops. In semiarid and arid lands, decreased crop yield and quality is often associated with soil salinization. Out of approximately 270 million hectares of irrigated land worldwide, 40% of the land is located in arid or semiarid regions where soil salinization generally occurs (Smedema and Shiati, 2002). These circumstances pose a challenging situation for forage growers who seek forage crops that can survive in dry and arid growing conditions for increasing livestock industries. Growing salt-tolerant forage crops in these regions with limited and poor water quality is an excellent opportunity to use saline water resources for forage production (Malcolm, 1996).

Alfalfa, a perennial leguminous forage crop that is relatively salt-tolerant regarding germination and early growth when irrigated with poor-quality water (Kankarla *et al.*, 2020), is the most valuable and widely adapted forage crop because it maintains most of its yield and all of its nutritive value under low to moderate salinity (Ferreira *et al*., 2015), being cultivated on over 35 million ha of land globally (Radović *et al*., 2009). Triticale is the most successful man-made annual cereal forage crop (Mergoum *et al*., 1992), cultivated on nearly 3.2 million ha globally and 0.4 million ha in the US, mainly for pasture and stored feeds such as hay and silage (Briggs, 2005). It is an annual winter or spring small grain developed by crossing wheat (*Triticum spp*.) and cereal rye (*Secale spp*.) that is also widely adapted to a range of soils and harsh climatic conditions, including dry and marginal lands, and produces high biomass (Lelley, 2006). It is an alternative to other cereals, particularly wheat (*T. aestivum*), in environments where growing conditions are unfavorable or in low-input systems (Mergoum *et al*., 1992; Erekul and Kohn, 2006) for high biomass production (Mergoum *et al.*, 1992). Our earlier research reconfirmed triticale as a salt-tolerant species (Kankarla *et al*., 2019).

Literature shows there is a dearth of information on the effects of irrigation water salinity on forage nutritive value. This preliminary study was done with the main objective of evaluating forage nutritive value of triticale and the first harvest of newly-seeded alfalfa, as representative forage species, under varied levels of saline irrigation water in the greenhouse.

MATERIALS AND METHODS

Duplicated, simultaneous experiments, each with four randomized complete blocks were conducted under controlled conditions in separate areas of the New Mexico State University, Fabian Garcia Science Center greenhouse at Las Cruces, NM, USA, for 90 days on alfalfa and triticale. The greenhouse meteorological data (air temperature, relative humidity, and photosynthetically active radiation) was recorded throughout the study period using a Watchdog 2475 Plant Growth Weather Station with SpecWare 9 Pro GH FGSC 2B software (Spectrum Technologies, Inc., Aurora, IL, USA). The day/night temperatures and relative humidity averaged 33.4/13.4°C, 84/8 % and the mean daily light integral was 11.6 mol m^{-2} day^{-1}. These conditions are similar to those during spring to represent environmental conditions during the seedling to first harvest maturity of a spring-seeded stand of alfalfa (Lauriault *et al*., 2020) as well as during the autumn to represent the environmental conditions during the vegetative growth phase of a winter cereal, such as triticale, prior to the onset of grazing (Marsalis and Lauriault, 2020). A common variety of each species was selected to avoid the influence of breeding improvement for salt tolerance to maximize the effect of salinity on seedling growth, previously published (Kankarla *et al*., 2019, 2020), which also would avoid similar effects on nutritive value.

Locally-collected sandy soil (93% sand, 3% silt, 4% clay) was air-dried, ground, sieved through a 2-mm sieve, and autoclaved at 80°C for 4 h. The experimental unit was a pot (20 cm depth and 18 cm diameter) filled with 3.94 kg of sand soil after its perforated bottom was lined with cheesecloth topped with gravel to prevent soil loss and allow free drainage. Soil was poured in increments to allow its uniform distribution within the pot. Pots were irrigated with fresh water three to four times to leach out the salts and bring soil EC to <1 dS m^{-1}. After leaching, ten seeds of the species designated for that pot were sown 2 cm apart in the top 1–2 cm of the soil (Marsalis et al., 2020). During the initial four weeks, pots with the seedlings were sub-irrigated with fresh water until the plants established. Fertigation was done with half-strength (approximately EC 0.9 dS m^{-1}) Hoagland solution (Hoagland and Arnon, 1950) until the initiation of two to three leaves.

There were four irrigation water treatments: fresh water (control; 0.7 dS m^{-1}), brackish groundwater (BGW; 4 dS m^{-1}), reverse osmosis concentrate (ROC; 8 dS m^{-1}; Ca dominant), and BGW plus sodium chloride (BGW+NaCl; 8 dS m^{-1}; Na dominant). The fresh water was drawn from the Las Cruces city water system, while the BGW and ROC were obtained from the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM, USA. The BGW+NaCl was prepared in the laboratory by adding 5.4 g L^{-1} of laboratory-grade NaCl (Innovating Science, USA) to BGW. Care was taken to thoroughly mix the NaCl until it dissolved completely. The ROC irrigation water was Ca and Mg dominant, while BGW+NaCl was Na dominant. Chemical properties of the water treatments are provided in Table 1. Irrigation treatments were introduced four weeks after emergence. Both species were irrigated with respective treatments along with the half strength Hoagland fertilizer solution when the saturated soil moisture content depleted to approximately 50% by species. Alfalfa needed to be irrigated every 9–10 days and triticale every 5–6 days. A total of 10 irrigations in alfalfa and 13 in triticale were carried out during the entire 90-day crop growth period. The higher irrigation frequency and number of irrigations for triticale were attributable to its higher aboveground biomass (Kankarla *et al*., 2019) and evapotranspiration as compared with alfalfa. Additional salinity applied due to fertigation was assumed to be equal across irrigation water treatments within species and therefore not a factor in differences among treatments, although it also likely would have led to increased soil salinity over time.

After 90 days of plant growth, when the alfalfa and triticale were still both vegetative, shoots were harvested by clipping at ground level and forced-air oven dried at 65°C for 3 days. Because of very limited harvested plant material (<16 and 22 g dry matter pot^{-1} for alfalfa and triticale, respectively; Kankarla *et al*., 2019), biomass was combined across experiments by crop and irrigation water treatment and then ground and sieved through 2-mm mesh for estimation of forage nutritive value analysis of crude protein (CP), acid detergent fiber (ADF), aNDF, NDF digestibility (NDFD), 48-hr in vitro true dry matter digestibility (IVTDMD), non-fiber carbohydrates (NFC), net energy for lactation (NEl), Ca, P, K, and Mg by near infrared spectroscopy (NIRS) by SDK laboratory (Hutchinson, KS, USA). Estimation of alfalfa nutritive value used the universal alfalfa hay equation and estimation of triticale nutritive value used the universal grass hay equation.

STATISTICAL ANALYSIS

Statistical analysis for forage nutrient value data was done using SAS PROC MIXED (version 9.4; SAS Institute Inc., Cary, NC, USA) with crop as the blocking factor and the crop x treatment interaction as the denominator for F tests, because of lack of any replication within forage crop species. Significance was defined at $P \leq 0.05$. Whenever a significant irrigation water treatment effect was found, least squares means were separated using least significant difference and the PDMIX800 macro (Saxton, 1998).

RESULTS AND DISCUSSION

Forage nutritive value is associated with the energy, protein, digestibility, fiber, mineral, and vitamin content in the forage and animal performance (Newman *et al*., 2007; Al- Dakheel *et al*., 2015). In this study, CP, ADF, aNDF, NDFD, IVTDMD, NFC, NEL, ash, and macronutrients (Ca, P, K, Mg) were used to evaluate forage nutritive value. The influence of irrigation water salinity on these forage nutritive value components 90 days after seeding of alfalfa and triticale as representative forage crops fed to a broad spectrum of livestock classes is presented in Table 2. The results show increased salinity decreased ADF, aNDF, and K content in the forage, but increased NFC with a trend (Ramsey and Schafer, 2002) toward increased Mg (Table 2). Greater ADF and aNDF is associated with decreased digestibility and intake in forage; hence, low fiber content is considered favorable for good forage nutritive value (DePeters, 2012). However, it was noticed that calcium-dominant ROC reduced ADF and K slightly more than Na-dominant BGW+NaCl, but there was no difference in the reduction for aNDF and Mg among non-control treatments (Table 2). Also, BGW and ROC treatments significantly increased NFC compared to BGW+NaCl. Similar to NFC, although not significantly, salinity with ROC increased CP (Table 2), which is in agreement with Suyama et al. (2007a), who also reported greater CP at greater salinity for *Paspalum*, creeping wildrye *[Leymus triticoides* (Buckl.) Pilger], and Bermudagrass (*Cynodon dactylon*). It is important to understand that crude protein is the most important nutrient for livestock as it supports rumen microbes that consequently degrade forage. Other studies by Mass and Grattan (1999) and Suyama *et al*. (2007b) also reported an increase in CP and a decrease in ADF under salinity stress in highly salt-tolerant alfalfa forage. As a rule of thumb, when aNDF is low in a forage, dry matter intake will be greater leading to increased animal performance (DePeters, 2012).

Mineral elements are essential nutrients required by animals to provide energy and improve their performance (McDowell *et al*., 2005). Important macro-minerals such as Ca and P form the main structural components of bones and teeth, K is needed for osmotic regulation, nerve impulse transmission, and enzyme reaction, and Mg is important because it activates several other enzymatic reactions (NRC, 2000). Therefore, it is important to know if salinity induced crop stress altered any of the nutrient composition of these forage crops. We observed that increasing salinity decreased K while significantly increased Mg at a higher salinity of ROC and BGW+NaCl (Table 2).

Table 1: Chemical properties of irrigation water treatments used to irrigate alfalfa and triticale in the controlled-environment greenhouse at Las Cruces, NM USA

Treatment[1]	Salinity (EC)	SAR	Na^+	Ca^{2+}	Mg^{2+}	K^+	Cl^-
	-----dSm^{-1}-----		- - - - - - - - - meq L^{-1} - - - - - -			- - - - - mg L^{-1} - - - - -	
Control[1]	<0.7	1.95	2.53	2.59	0.79	5.33	57.2
BGW	4	3.69	15.87	20.4	16.54	6.74	697.7
ROC	8	5.28	30.09	34.88	30.12	14.0	892.7
BGW+ NaCl	8	12.02	50.11	18.78	15.98	17.67	2024.3

[1]The control water was from the City of Las Cruces municipal potable water plant; BGW and ROC signify brackish groundwater and reverse osmosis concentrate, respectively, obtained from the Brackish Groundwater National Desalination Research Facility, Alamogordo, NM, USA.

Table 2: Influence of irrigation water salinity on forage nutritive value at 90 days after planting in the controlled-environment. greenhouse at Las Cruces, NM USA. Data are the means of two crops (alfalfa and triticale as representative species blocking factors)

	Salinity	**Nutritive value variable**															
Treatment	**(EC)**	**CP[1]**	**ADF**		**aNDF**		**NDFD**	**IVTDMD**	**NFC**		**NEl**	**Ca**	**P**	**K**		**Mg**	
	dSm-1	- - - - - - - - - - - - - - - - g/kg - - - - - - - -									Mcal/kg	- - - - - - - - g/kg - - - - - - - -					
Control[2]	<0.7	168	274	A[3]	374	A	522	828	317	C	1.342	16.5	2.4	23.8	A	3.50	B
BGW	4	168	237	BC	309	B	484	839	395	A	1.441	17.0	2.5	20.1	B	4.55	AB
ROC	8	177	232	C	300	B	433	829	394	A	1.430	17.0	2.6	17.8	C	5.65	A
BGW+NaCl	8	175	249	B	319	B	461	834	364	B	1.386	18.1	2.5	19.5	BC	5.75	A
	SED	8	5		15		30	14	7		0.034	0.5	0.3	0.6		0.5	
	P-value	0.6498	0.0084		0.0483		0.1845	0.8601	0.0034		0.1686	0.1913	0.9548	0.0086		0.0601	

[1]CP, ADF, aNDF, NDFD, IVTDMD, NFC, and NEl signify crude protein, acid detergent fiber, amylase-treated neutral detergent fiber, NDF digestibility, in vitro true dry matter digestibility, non-fiber carbohydrates, and net energy for lactation, respectively.
[2]The control water was from the City of Las Cruces municipal potable water plant; BGW and ROC signify brackish groundwater and reverse osmosis concentrate, respectively, obtained from the Brackish Groundwater National Desalination Research Facility, Alamogordo, NM, USA.
Means within a column followed by the same letter(s) are not significantly different at P < 0.05.

CONCLUSIONS

The effect of irrigation water salinity on forage nutritive value was based on NIRS estimates of shoot biomass of two representative forage species harvested 90 days after planting in a preliminary greenhouse study under controlled conditions. The results of this study demonstrate the feasibility of using available poor-quality irrigation water, especially BGW and ROC, establishing to possibly increase some components of nutritive value during establishment of salt-tolerant forage crops. The results pertain more strongly to triticale and other cool-season annual forage crops as the data were collected consistently to the vegetative maturity of the triticale when it would first be grazed. The results are more limited for alfalfa as a perennial crop that would be harvested about 90 days after planting in the seeding year of a spring seeding followed by additional harvests that year, as well as multiple times each subsequent year throughout the life of the stand. Over the life of the stand, the influence of poor-quality irrigation water on nutritive value may change and as would possible deterioration of soil quality, which could lead to reduced yields and shortened stand-life of alfalfa. Consequently, further research at the field level over a longer term is needed to validate the results of this preliminary study and to evaluate the influence of poor-quality water for irrigating these and other forage crop species.

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