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Establishment, Growth and Irrigation Requirements of Kentucky Bluegrass and Tall Fescue as Influenced by Two Irrigation Water Sources

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Abstract: This study was conducted under a dual Line Source Irrigation System (LSIS). Both LSIS covering 380 m^2 (24 by 16 m) were laid out in a West-East direction and separated by a 15 m wide turf buffer zone. The LSIS in the east side received municipal potable water [Electrical Conductivity (EC) = 0.12 dS m^{-1}]. The west LSIS received saline well water (EC = 3.0 dS m^{-1}). Each LSIS was then equally divided into 12 plots in which Kentucky bluegrass and tall fescue were seeded in strips along the irrigation gradients. Data were collected on turf establishment, soil salinity, soil pH and drought responses. Saline well water irrigation increased soil salinity, sodium adsorption ratio and pH. Salty well water irrigation dramatically reduced and delayed the germination of Kentucky bluegrass, whereas tall fescue germination and establishment were unaffected when compared with potable water irrigation. Grasses subjected to well water irrigation exhibited greater iron chlorosis. Under moderate drought conditions tall fescue survived drought conditions better and required less irrigation to maintain acceptable quality. However, under severe drought conditions when soil moisture was depleted in deep soil profile, tall fescue did not show advantages in drought resistance over Kentucky bluegrass.

Key words: Saline well water, irrigation, potable water, germination, drought resistance, iron (Fe) chlorosis, survival

INTRODUCTION

With the rapid growth of population and potential changes of climate, water availability may become a limiting factor for the future growth of the turf industry in the arid and semiarid regions of the world. It is, therefore, important to minimize the consumption of irrigation water while maintaining high quality turfgrass. This can be achieved by irrigation upon require without over irrigation and by selecting turfgrasses that are able to survive over longer periods of time on the same amount of water and without loss their quality (Dane *et al*., 2006). Drought is a common environmental stress causing the decline and loss of turfgrass and the development of drought tolerant turf cultivars will be of great value to turf managers. Earlier studies have reported that turf established from seed with strong drought resistance may reduce the use of irrigation water by more than 50% (White *et al*., 1993; Liu *et al*., 2001). Therefore, the identification and selection of turfgrass species with strong

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drought resistance are important in developing turf in arid and semi-arid regions. Researchers have put significant efforts in evaluating turfgrass drought resistance (Aronson *et al.*, 1987; Carrow, 1996a, b; Fry and Butler, 1989; Gibeault *et al.*, 1985; Kim and Beard, 1988; Qian *et al.*, 1997; Qian and Engelke, 1999; Jiang and Huang, 2000, 2001; Binger and Hongwen, 2000; Liu *et al.*, 2001, 2008; Carrow and Duncan, 2003; Abraham *et al.*, 2004; Chai *et al.*, 2006; Dane *et al.*, 2006; Su *et al.*, 2007; Karcher *et al.*, 2008). The results of these studies clearly indicate that turfgrasses differ in their performance during drought events. However, considerable variability in rankings of relative drought resistance has been reported. Several researchers have investigated the difference in irrigation requirements between Kentucky bluegrass and tall fescue. Sheffer *et al.* (1987) stated that tall fescue is better able to avoid drought than other cool-season turfgrasses such as Kentucky bluegrass (*Poa pratensis* L.). In California, Gibeault *et al.* (1985) reported that tall fescue can maintain its quality when irrigated at 60% pan evaporation while Kentucky bluegrass needs the amount of water equal to 80% pan evaporation to maintain its quality. Dane *et al.* (2006) evaluated two hybrid bluegrasses (HB 129 and HB 329) and two tall fescue cultivars (Southeast and Rebel III) for maintaining their desirable characteristics (minimal browning) during different water stress levels. It was concluded that, the two hybrid bluegrasses were able to survive stress periods better than the two tall fescue cultivars.

Fry and Butler (1989) demonstrated that field-grown Rebel tall fescue maintained acceptable quality when watered every 2 days at 50% of tall fescue's potential ET. In Nevada, tall fescue requires 80% potential ET to maintain acceptable turf quality. However, within tall fescue species cultivar variation in drought resistance has been reported which attributed mainly to differences in total root length density and rooting depth (White *et al.*, 1993; Carrow, 1996a; Binger and Hongwen, 2000). At Colorado State University, researcher's investigated 16 cultivars of Kentucky bluegrass for their relative drought resistance. Their results indicated that Livingston, Merion and SR2000 displayed superior drought resistance relative to the other cultivars. Chai *et al.* (2006) assessed drought resistance in 11 of Kentucky bluegrass varieties and indicated that Baron and Barlin had better resistance to drought than other varieties and suggested that they are suitable for sowing in arid and semi-arid regions because of their strong drought resistance at the seedling stage. Liu *et al.* (2008) investigated the responses of five Kentucky bluegrass cultivars subjected to drought and high temperature stress conditions. They found that the five cultivars of Kentucky bluegrass declined in their turf quality and increased in their leaf wilting from 3 to 21 days under both stresses. It suggested that the duration of drought stress is the main factor that affects the turf quality and leaf wilting in the northwestern arid region of China.

To reduce the use of potable water, more and more turf facilities are using marginal quality water, such as saline well water, ditch water and effluent water for irrigation. Some of these alternative water sources contain significant concentrations of dissolved salts. Information is needed concerning the influence of irrigation water quality on turfgrass establishment and growth, drought resistance and irrigation requirements. The lack of data in this aspect is because most of the university research sites only have a single water source available, which are usually municipal potable waters. However, whether unintentionally or planned, irrigation with underground well water or effluent water is common in many large turf facilities in arid and semiarid regions. It is expected that this practice will increase, especially in areas where potable water is either short or expensive. Well water or effluent water often contains dissolved salts. It is essential that turf managers have information regarding the effects of different water sources with contrasting quality on turfgrass establishment, turf quality, pest invasion, soil salinity and sodicity and water requirements.

This study was designed to evaluate turfgrass establishment, soil salinity and sodicity, pest invasions and drought resistance of Kentucky bluegrass and tall fescue as affected by irrigation water sources.

MATERIALS AND METHODS

Experimental Design

The experiment was conducted at the Colorado State University Horticulture Field Research Center, Fort Collins, CO on a Nunn clay loam soil (fine montmorillonitic mesic aridic argiustoll). The climate is semi-arid with an average annual precipitation of 365 mm. Dual Line Source Irrigation Systems (LSIS) were installed in the summer of 1998. The LSIS in the east side received municipal potable water and the west received saline well water. Both LSIS covering 380 m^2 (24 by 16 m) were laid out in a West-East direction and separated by a 15 m wide turf buffer zone. Each LSIS consists of a single row of in-ground irrigation heads (Hunter PGP sprinkler heads, Hunter Industries Inc., CA) located in the middle of the study area, spaced 4 m apart, which is approximately 1/3 of the maximum throw of each sprinkler irrigation head. This sprinkler arrangement is designed to generate a perpendicular irrigation gradient, i.e., decreasing irrigation volumes with increasing distance from the irrigation line source (Hanks *et al*., 1976; Qian and Engelke, 1999).

The average and standard error of water quality values and nutrient contents of the two water sources were shown in Table 1. As compared to municipal water, the well water on this site exhibited high salinity, high sodium content and high bicarbonate.

Each LSIS was then equally divided into 12 plots, measuring 4 m by 16 m, in which SR-2100 and NuStar Kentucky bluegrass and Rebel 3D tall fescue were seeded in strips along the irrigation gradients and by following a randomized complete block design with four replications. Kentucky bluegrass and tall fescue were selected because they are the most commonly used turfgrasses in Colorado.

Turfgrass Establishment

Plots were seeded at the optimum seeding rates (245 kg ha^{-1} for bluegrass and 392 kg ha^{-1} for tall fescue) on September 20, 1998. During establishment, irrigation was uniformly applied using LSIS and two additional outside irrigation lines. Turfgrass establishment was determined in November 1998 by visually rating the plot area that is covered by turfgrass. Due to the poor establishment, bluegrass plots were aerated and seeded again on May 30, 1999. Turf establishment was rated again on August 1, 1999.

Table 1: Analysis of irrigation waters

Parameters	Municipal water	Well water
pH	7.50	8.2
Ca^{++} (mg L^{-1})	11.20	417.0±12.9
Mg^{++} (mg L^{-1})	1.10	171.0±17.8
Na^{+} (mg L^{-1})	5.30	193.0±16.3
K^{+} (mg L^{-1})	0.00	6.0±0.80
B (mg L^{-1})	0.03	0.4±0.08
CO_3^{-} (mg L^{-1})	<0.01	<0.01
HCO_3^{-} (mg L^{-1})	56.90	403.0±21.2
SO_4^{-} (mg L^{-1})	0.00	1679.0±80.5
Cl^{-} (mg L^{-1})	0.80	43.0±6.00
NO_3^{-} (mg L^{-1})	0.70	42.0±6.80
EC (dS m^{-1})	0.10	3.1±0.15
SAR		2.1±0.14

Data is expressed as Mean±SE

Irrigation

Plots were well established by the fall of 1999. Due to a great weed invasion, Buctril and Trimec were applied on July 14, 1999. All grasses were mowed twice weekly at 6.4 cm with clippings returned. Nitrogen was applied at the rate of 49 kg ha^{-1} in May and September. Since, one of our objectives was to assess the irrigation effects on pest incidence, no herbicides or fungicides were applied after turf establishment.

From the summer of 2000 to 2002, irrigation was applied only through the LSIS every 3-4 days at a rate of 120% of the previous 3 or 4 days Penman-Kimbly model estimated ET to the area 1.2 m away from the central irrigation line. As the distance from the central line increased, turf received less and less water. Irrigation was applied from 4:00-6:00 HR when wind speed was typically the lowest. The weather station used for ET estimation was located approximately 50 m Northeast of the experimental area.

Water distribution along irrigation gradients was determined at least monthly by using rain gauges positioned at 1.3 m increments from the irrigation line source. Periodic adjustments were made to ensure that the desired water distribution was maintained. Data on irrigation output along the gradient were converted to an equivalent of ET% (Fig. 1a, b). Despite efforts to water only when wind was minimal, the water distribution curve was still skewed slightly to the Southern side of the LSIS.

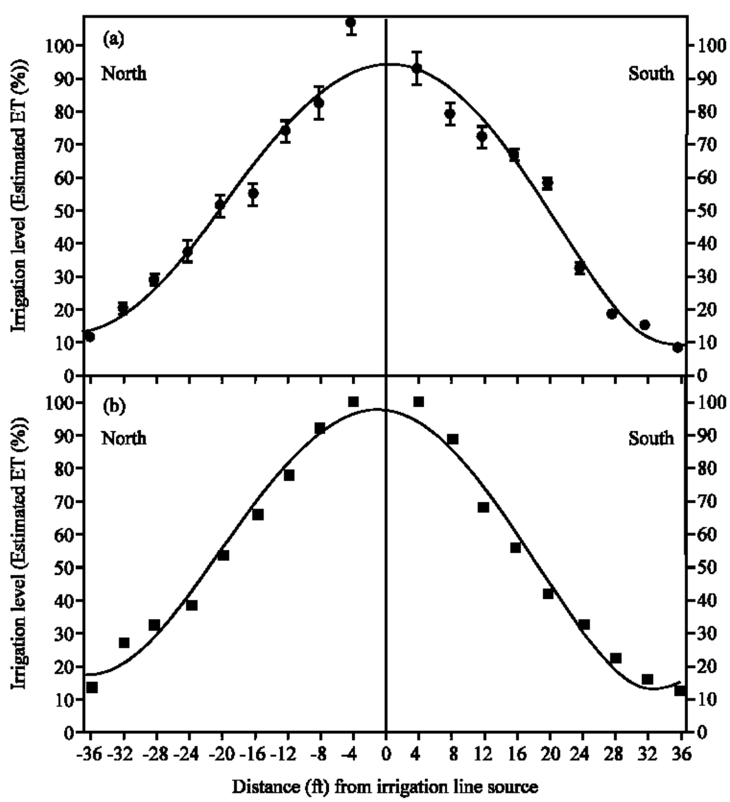

Fig. 1: Irrigation distribution of the line source irrigation systems using (a) potable water and (b) well water

To assess relative drought resistance of the selected turfgrasses, the distance between the central irrigation line and the position at which the turf could not maintain acceptable quality due to drought stress was determined during summer drought periods. Turf plots with wilt occurring further from the central line indicate better drought tolerance Table 3.

Measurements of Soil Salinity, SAR and pH

Soil samples were collected by sampling two (5.7 cm in diam.) soil cores at 1.2 m from the irrigation line source in 1999 and 2002 and from 1.2 and 4.9 m from the irrigation line source in 2001 and 2002. Soil samples were taken from each plot to a depth of 10 cm below the thatch layer. The soil samples were air-dried and ground with a porcelain mortar and pestle and passed through a 2 mm sieve. Electrical conductivity, pH and Na, Mg and Ca content of saturated paste extract were determined with Hach soil salinity and pH appraisal kits (Model CO150, Hach Company, Loveland, CO).

Weed Invasion and Iron Chlorosis

In June 1999, August 2000 and 2001 data were collected for the type and coverage of the primary weeds.

Iron chlorosis was assessed at least twice per year by visually examining the interveinal yellowing pattern (a typical iron chlorosis symptom) and rating turf canopy color on a 1-9 scale with 9 = Dark green color and 1 = Complete bleached color.

Data Analysis

Analysis of Variance (ANOVA) was used to test the effects of turfgrass species, water source and their interaction, although water source is not randomized. Percentage data (e.g., turf% ground cover, weed% invasion) were first arcsin transformed to satisfy the normality assumption of ANOVA. When F values were significant, means were separated using an LSD test at $p = 0.05$.

RESULTS AND DISCUSSION

Soil Salinity, pH and Sodicity

Salt build-up was observed in the well water irrigated site as indicated by the consistently high EC value of saturated soil paste (Fig. 2a). Soil pH was higher in the well water irrigated site than potable irrigated site only in 2001 (Fig. 2b). However, considering the high salinity in the well water, soil salinity in the study site was low. This was because the salts in the well water were mainly SO_4^{2-}, HCO_3^- and Ca^{2+}. These salts can precipitate in soil (to form salt crystals), which prevented a greater increase in salinity of soil solution. Well water irrigation also increased soil sodium absorption ratio, compared to potable water irrigated plots during 2000-2002 (Fig. 2c).

Establishment

Well water irrigation dramatically reduced and delayed the germination and establishment of NuStar and SR 2100 Kentucky bluegrass, whereas Rebel 3D tall fescue germination and establishment were not affected when compared with potable water irrigation. Compared to the September seeding, Kentucky bluegrass plots seeded by the end of May exhibited better establishment (Fig. 3a, b). Qian and Suplick (2001) found that as salinity increased, the temperature window to achieve acceptable germination was narrowed; this trend was more pronounced in Kentucky bluegrass than tall fescue. Kentucky bluegrass

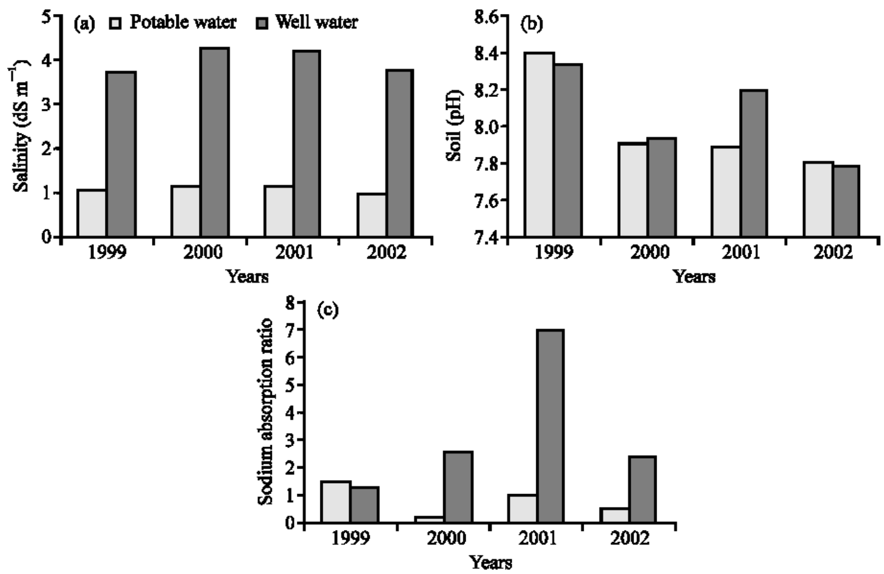

Fig. 2: (a) Soil salinity, (b) pH and (c) Sodium Absorption Ratio (SAR) as affected by irrigation waters

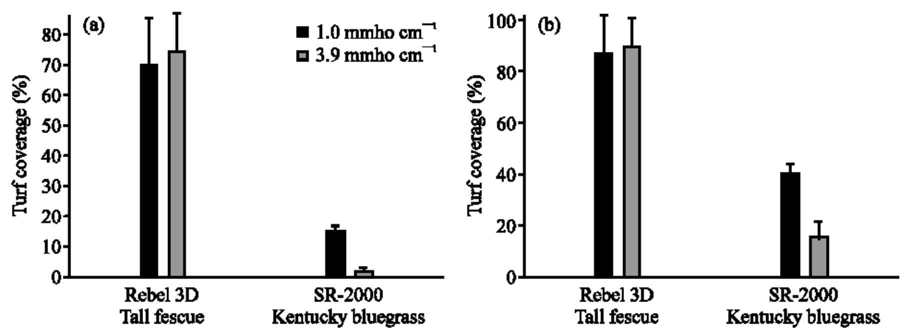

Fig. 3: Effects of salinity on the establishments (turf coverage (%) of tall fescue and Kentucky bluegrass. Turf establishment was rated about 2 months after seeding, (a) in 20th Sept. 1998 and (b) in May 1999

seeds, emerging slowly and exhibiting great sensitivity to salinity during germination, may be seeded in a very narrow window to achieve acceptable germination under saline conditions. When seeded in September, salinity likely delayed turfgrass seed germination to late in the fall, likely resulting in poor establishment.

Iron Chlorosis

Turf grown under potable water irrigation exhibited minimal iron chlorosis. However, plots receiving well water irrigation exhibited different levels of iron chlorosis from June to October during 2000-2002 (Table 2). Chlorosis was most severe when irrigated with saline well water and when the turf did not receive sufficient irrigation (<70% ET). Among three grasses, NuStar KBG showed the most severe chlorosis. Harivandi and Butler (1980) reported

Table 2: Iron chlorosis of three turfgrasses as affected by irrigation water quality and irrigation levels

	Date							
	8/23/00		8/1/01		6/13/02		8/23/02	
Grass	Potable	Well	Potable	Well	Potable	Well	Potable	Well
Irrigation based on ET								
Nustar Kentucky bluegrass	0	2.75a	0.68a	6.5a	0.67a	5.25a	0	4.5a
SR-2000 KBG	0	0.75b	0.25ab	3.3b	0.25ab	1.63b	0	3.0b
Rebel tall fescue	0	1.50b	0.00b	1.9b	0.00b	2.38b	0	2.0c
Deficit irrigation								
Nustar Kentucky bluegrass					0.68	6.5a	0.38	5.0
SR-2000 KBG					0.75	3.12	0.75	3.9
Rebel tall fescue					0.25	5.00	0.25	2.5

Mean separation with different letter(s) within columns by Fisher's LSD test, $p \leq 0.05$. Iron chlorosis was assessed by visually examining the interveinal yellowing pattern (a typical iron chlorosis symptom) and rating turf canopy color on a 1-9 scale with 9 = Dark green color and 1 = Complete bleached color

Table 3: Wilt line (feet) of five turfgrasses under a line source irrigation system

	Date					
	Quality line		June 3, 2002		August 23, 2002	
Grass	Potable	well	Potable	Well	Potable	Well
Nustar Kentucky bluegrass	14.0b*	7.0b	14.8ab	15.2ab	11.75a	11.5a
SR-2000 KBG	13.5b*	7.5ab	18.4a	16.2a	11.75a	11.3a
Rebel tall fescue	15.5a*	8.3a	13.2b	13.0b	9.75b	9.75b

Mean separation with different letter(s) within columns by Fisher's LSD test, *$p \leq 0.05$

that iron chlorosis varied among Kentucky bluegrass cultivars. Cultivar SR2000 Kentucky bluegrass appeared to be more resistant to iron deficiency than Nustar.

Although, the soil pH did not differ between the well water and potable water irrigated plots on most of the testing dates, the higher bicarbonate content may have likely induced the iron deficiency symptom.

Drought Resistance

During 1999-2001, no consistent difference in drought resistance between potable and well water irrigation treatments (Table 3). In 2002, turfgrasses in the well-water-irrigated site required greater amount of water to maintain turf quality in one of three ratings.

During early stage of the study, under moderate drought conditions and when moisture was available in deep soil profile (>30 cm), tall fescue survived drought conditions better and required less irrigation to maintain acceptable quality. However, under severe drought conditions when soil moisture was depleted in deep soil profile, tall fescue did not show advantages in drought resistance over Kentucky bluegrass. Tall fescue is a widely grown cool-season turf cultivar in the northern, transitional and upper to mid-South climates of the United States. Compared with other cool-season turf grass cultivars, it is considered as the most drought resistant cool-season turf due to its deep and extensive root system. However, under continuous deficit irrigation in the semi-arid climates, such as Colorado where a large proportion of the water comes from irrigation, deep root systems may not be as beneficial as they are in the mid-west and east where periodic significant precipitation recharges the soil water in the deep soil profile regularly. This result supports the findings of Qian *et al*. (1997), who stated that tall fescue relies primarily on deep and extensive root systems to maximize water uptake, yet it has a high evapotranspiration rate and poor recovery after exposure to severe drought stress.

Weeds Invasion and Winter Mites Infestation

The primary weed species were pigweed, spurge, mallow and purslane during establishment and dandilion after establishment. Irrigation water sources had significant effects on weed invasions during turf establishment. More pigweed, spurge, mallow and purslane were observed in the plots irrigated with saline well water. This may be because slow germination and lower turf coverage provided open spaces for weed invasions. However, more dandelion and prickly lettuce were counted in potable-water-irrigated plots, compared with plots irrigated with well water. This result implied that dandelion and prickly lettuce might be sensitive to salinity. Water with high soluble salt levels may be able to substantially reduce problems related to dandelion invasions.

Due to the additive stress effects of drought and soil salinity. More severe winter mite damage was observed in well water site compared to potable water irrigated-site (data not shown). Mite infestation, occurred mainly in the fall and winter with symptom showing up in the spring, was encouraged by water stress. Marginally high salinity appeared to escalate mite infestation by inducing osmotic stress.

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