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In recent years, several non-traditional methods of water conditioning including magnetic, electromagnetic, catalytic, and electrochemical water conditioning, have been proposed to improve irrigation efficiency. Researchers at Oklahoma State University investigated the performance of one such device, the Care Free Water Conditioner, which has been claimed as having an effect on plant growth, as well as soil physical and chemical characteristics.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 225 projects at a cost of $21 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Can Non-traditional Water Conditioning Devices Help Address Irrigation Water Quality and Quantity Issues?

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SUMMARY

Access to an adequate quantity of suitable quality irrigation water is essential to the future of the golf course industry. Questions exist concerning whether non-traditional water conditioning devices can negate the effect of poor quality irrigation water or the effect of reduced amounts of irrigation water applied. This research assessed the short-term (one month or less) effects of using catalytically treated poor quality irrigation water, as well as the effects of deficit irrigation on visual quality, growth and water-use efficiency of Tifway [Tifton 419] (*Cynodon dactylon* x *C. transvaalensis*) bermudagrass growing under simulated golf course fairways conditions at Stillwater, OK.

- Water treated with the Care Free unit had no effect on Tifway visual quality, clipping yield, or water use efficiency, regardless of the amount or quality of irrigation water utilized.
- Conditioned water had no impact on total soluble salts, sodium adsorption ratio, sodium ion, exchangeable sodium percentage, pH or electrical conductivity of the soil.
- The studies were of inadequate duration for the high salinity water treatments to affect bermudagrass visual quality, clipping yield or water use efficiency.
- Tifway quality and clipping yield declined when irrigated with amounts that were less than 75% of evapotranspiration on a cumulative 3-day basis.

Access to an adequate quantity of suitable quality irrigation water is essential to the future of the golf course industry. Quantity is the amount of water available while quality is the fitness of the water for the intended use. Irrigation water quality can be degraded by a number of factors which include, but are not limited to, excessive turbidity, soluble salts, suspended solids, sodium, pH, bicarbonates, and specific ions such as boron (7).

Several methods of improving the quality or fitness of irrigation water are available (1,7). Filtration is used to mechanically remove suspended solids in water by trapping them on screens. Aeration treatment introduces air or ozone into water to aide in chemical or biochemical breakdown of select compounds, suppression of algae or to destroy human pathogens. Chlorination is also often used to destroy the viability of human pathogens when effluent is used for irrigation.

Some of the most common treatment systems used for working with poor quality irrigation water caused by high sodium, high bicarbonate, and high pH include treatment of the soil with sulfur or calcium sulfate (gypsum) or treatment of water with proportioning systems or direct treatment of the water with acid injectors and sulfur burners (2, 6, 7, 8). Proportioning systems dilute a lower quality source of water with a higher quality source. Acid injection systems inject an acid, most commonly sulfuric acid, urea sulfuric acid, or phosphoric acid, into the water. Sulfur burners

Figure 1. The Care Free Water Conditioner, classified as a catalytic water conditioning device, is shown hooked to irrigation hose and a DC voltage converter in an "active water treatment" setup.

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oxidize elemental sulfur and inject sulfur dioxide gas into water where it eventually converts into sulfuric acid, providing the same benefit as acid injection. Another method, but less common is use of reverse osmosis, where selective membranes or electrical methods improve water quality by reducing salt (ion) load in the water (3). The mechanisms by which these various traditional treatments improve water quality and management strategies for their usage can be found in Harivandi et al. (7).

Several non-traditional methods of water conditioning have been proposed in recent years (5, 12). A review of available literature on these non-traditional methods by the author should not be viewed as an endorsement of the legitimacy of these methods. The use of some non-traditional methods is considered controversial (12) and the legitimacy of some proposed mechanisms of treatment has been questioned (9). Non-traditional methods, which can include magnetic, electromagnetic, catalytic and electrochemical water conditioning, have been proposed to reduce the formation of scale in water lines, water heaters, boilers and cooling systems (5).

Use of these devices has also been proposed to reduce the detrimental effects of poor quality irrigation water on plant growth as well as soil physical and chemical characteristics. One such device, classified as using a catalytic method of water conditioning, and which has been suggested as having an effect on plant growth or soil physical or soil chemical characteristics, is the Care Free Water Conditioner (Lew Ground, Hydrotek Management, Las Vegas, NV, personal communications; 4,11).

While testimonials are plentiful on the successes achieved through the use of electromagnetic, catalytic and electrochemical methods, a review of scientific literature yielded no information concerning their efficacy in reducing the deleterious effects of poor quality water or deficit irrigation on plant growth or soil characteristics. While these methods may be useful for control of scaling of pipes and boilers as proposed in FEMP (5) and West (12), golf course irrigation systems, as well as the irrigated soil-plant environment, are open and dynamic systems. Different mechanisms can be involved in the formation of boiler scale as compared to degradation in water quality or soil physical or chemical characteristics due to high soluble salts or high specific ion content, such as elevated sodium or boron levels.

The Information Gap and Objectives to Address It

Starting in the late 1990's, a number of inquiries were made to Brian Maloy, former USGA Green Section Mid-Continent agronomist, and the author concerning the effectiveness of non-traditional water conditioning methods in improving turf response to poor quality water or to drought stress resulting from water deficits. Product advertising claims and testimonials coupled with increased inquiries and lack of research-based performance information was the stimulus for this investigation.

While many non-traditional water conditioning devices are available, limited resources and the complexity of the questions posed forced a very targeted research response. The specific objectives of this work were to test the short-term effects of using catalytically treated poor quality irrigation water, as well as deficit irrigation, on visual quality, growth, and water use efficiency (WUE) of Tifway bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) growing under simulated golf course fairways conditions.

How The Research Was Conducted

Water Treatment Device

The device chosen for testing was the Care Free Water Conditioner (abbreviated CFWC). This unit is an example of a non-chemical, catalytic water treatment device (Lew Ground, Hydrotek Management, Las Vegas, NV, personal communications). Statements regarding the mechanism of water treatment by the CFWC were selected from literature provided by Hydrotek Management and have not been verified by the author. The author treated the CFWC as a "black box" technology for the purposes of this test.

Figure 2. Jeff Gazaway guides the conditioned water into containers for temporary storage before it is precision applied to test plots.

Literature on the CFWC unit states that several different types of metals are housed in a water canister to draw in extra electrons from a grounded electrical outlet (110V outlet with a 1.0V to 3.0V transformer). Water is forced through the CFWC treatment unit. Inside the unit, water passes through multiple venturies and over dissimilar precious and semiprecious metals, picking up electrons. Those marketing the unit claim that by using ionic conversion, calcium and other agents in their ionic form are neutralized into stable molecules. These hardness minerals are said to not stick to materials that are normally scaled by hard water.

Water Conditioner Setup

The CFWC [Part: CFC 14, Model #1, 1/4 inch inlet/outlet] was adapted to a ¾-inch garden hose receiving water flow from an AC powered in-line pump. The specific CFWC unit tested was a smaller version of one available for use in-line, in a typical pump station application. The CFWC of choice for this research was rated for a water input flow of 1.1 to 2.6 gpm. The author used a flow rate of 2.0 ($\pm$ 0.1) gpm in both studies. Flow rate was verified periodically during each irrigation event using graduated cylinders.

The CFWC was set up as an "active treatment" system by connecting it to a DC voltage converter powered by a small portable gas-powered generator (Figure 1). As per manufacturer's suggestions, the unit was connected to the positive terminal of a 1.0 ($\pm$ 0.01) V DC source. The voltage potential difference to ground was verified not only at the positive terminal of the DC source, but also between the water stream exiting the CFWC

Manufacturers inlet water parameter requirements for the Care Free Water Conditioner

Temperature :	35 F to 225 F
pH:	6.5 to 8.5
Iron:	<0.3 ppm
Manganese:	<0.05 ppm
Hardness:	0.0 to 60 grains
TDS:	0.0 to 3,000 ppm

Characteristics of our high-salt (salt-amended) water treatment

Sodium:	318 ppm	pH:	8.3
Calcium:	22 ppm	Electrical Conductivity:	1.512 mhos/cm
Magnesium:	14 ppm	Totals Soluble Salts:	1426 ppm
Potassium:	5 ppm	Sodium Adsorption Ratio:	13.0
Nitrate:	<1 ppm	Potassium Adsorption Ratio:	0.1
Chloride:	53 ppm	Residual Carbonates meq:	14.07
Sulfate:	18 ppm	Sodium Percentage:	86.0
Carbonate:	0 ppm	Hardness:	112.5 ppm
Bicarbonate:	996 ppm	Class:	Moderately Hard
Boron:	0.09 ppm	Alkalinity:	816 ppm
USDA Class:	C3-S3 (*high salinity/high sodium risk*)		

Table 1. Manufacturer's inlet water parameter requirements and analysis of our salt spiked water (prior to conditioning treatment). Salt-amended water had 1,200 mg per liter of sodium bicarbonate added to a Lake Carl Blackwell water source.

and ground using a digital multimeter.

A non-potable water source (Lake Carl Blackwell, Stillwater, OK) was used as the base water source (low salt load) in both studies. To create the high sodium/high salinity hazard water treatments (Table 1), the base water source was modified with 1,200 mg/l (ppm) of sodium bicarbonate (household baking soda). To apply CFWC conditioning to the water, the low salt content or high salt content water was first created in a 40 gallon plastic container before being pumped through the CFWC to apply the conditioning effect (Figure 1). This conditioned or treated water was pumped into separate 40-gallon plastic containers (Figure 2) for temporary storage (less than 30 minutes) before being hand-applied to test plots via a hand-held sprinkler can (cover figure). All apparatus involved in water treatment, transfer and storage were cleaned and purged with the fresh water source extensively between treatments to avoid cross contamination.

Experiment I

The first experiment to evaluate the effects of water treated with the CFWC was conducted at the Turfgrass Research Center at Oklahoma State University-Stillwater, OK from July, 29 through August 25, 2000. The study was concluded immediately upon a saturating rainfall event. The study area was comprised of Tifway hybrid bermudagrass mowed at 0.5 inches, three times per week. The turf was fertilized with 4 lbs of N per 1,000 sq. ft. per growing season, with soil phosphorus and potassium test indices kept at or above the levels of 65 lbs/A of P and 250 lbs/A of K. Each plot in the trial measured 3 x 8 ft, and a 6-inch border was present around each plot.

A randomized complete block experimental design with three replications of each treatment was used. A total of 8 irrigation treatments were used, with a 2 x 2 x 2 factorial arrangement of treatments. Factors tested were the use of CFWC-conditioned or nonconditioned water, high salt (amended) or low salt (non-amended) water, and irrigation at 75 or 100% of estimated potential evapotranspiration (ET). Irrigation treatments were precisely applied using a sprinkler watering can. Irrigation was applied every three days as a percentage of the potential ET over the previous three days as estimated by a Penman-Monteith equation and the computational procedures by Kizer (9). Meteorological conditions used in ET calculations were monitored at an Oklahoma MESONET Weather Station located 0.5 miles from the test site.

<u>Monitoring Treatment Performance on Turf and Soil</u>

To assess the effect of the watering treatments, the treated turf was evaluated for visual quality once per week using the NTEP rating scale of 1-9, where 9 = excellent quality and 1 = poor quality turf. Although the turf was mowed three times per week, clippings were gathered twice per week from an 8 ft x 22-inch swath width down the middle of the plot. Clippings were oven dried in a forced-air oven at 49 C($\pm$ 2) C for at least three days before weighing. Clipping dry matter yield is a direct measure of shoot growth and an indirect measure of turf health and of recuperative potential.

Water use efficiency is an index that is calculated by dividing the weight of clipping dry matter produced per unit of water applied. The larger the index the more efficient the turfgrass in using the water for shoot growth. A single 4.25-inch diameter x 3-inch plug of soil was taken from the center of each plot on August 28, 2000, and the soil in the plug was tested by the Oklahoma State University Soil-Water-Forage Lab for total soluble salts, sodium adsorption ratio, sodium ion content, exchangeable sodium percentage, pH and electrical conductivity.

All of the performance parameters collected from the turf and soil were subjected to an analysis of variance (ANOVA) procedure, and if determined to be statistically appropriate (at the 95% certainty level or $p<0.05$), additional comparisons were made.

<u>Experiment II</u>

The second experiment was conducted August 22 through Sept 24, 2000 in an adjacent area using the same cultivar, cultural management regime, and data collection method as described for the first experiment. The study was concluded immediately upon a saturating rainfall event. Watering treatments tested in this experiment were made every three days, as a percentage of the cumulative potential estimated ET over the previous three days as in experiment I. In the second experiment treatments consisted of a nonwatered control and plots watered at 25%, 50% and 75% of the 3-day total ET, using high salt content (amended) conditioned water and high salt non-conditioned water.

Findings

<u>Experiment I</u>

An analysis of variance (ANOVA) procedure revealed that Tifway visual quality, clipping yield and water use efficiency (WUE) was not affected by water conditioning with the CFWC unit. In other words, regardless of the amount of water applied and whether the water was high in salt or not, conditioning of the water source with the CFWC unit had no effect on the plant performance measured in this study.

The CFWC unit did not affect the total soluble salts in the soil, the sodium adsorption ratio, sodium content, exchangeable sodium percentage, soil pH, or soil electrical conductivity. All test plots received a visual quality rating of 8 for the duration of this first study, thus neither the irrigation rate, water salinity, or CFWC conditioning had any effect on Tifway visual quality.

The salt/sodium content of the water did not affect Tifway's quality, clipping yield and or water use efficiency. The duration of the study was not adequate for hazardous amounts of salts to accumulate and affect plant growth. The high salt content water significantly increased the sodium adsorption ratio (8.7 vs 3.8), the sodium level (229 ppm vs 119 ppm), the exchangeable sodium percentage (10.1% vs 4.1%) and soil pH (7.2 vs 6.8) relative to plots treated with low salt content

Watering Treatment (% of ET)[2]	Turfgrass Quality[1]				
	8/25/00	8/28/00	9/09/00	9/15/00	9/18/00
75	7.0	7.0a	7.0a	7.0a	6.0a
50	7.0	6.2a	5.8b	5.8b	4.8b
25	7.0	5.2b	4.2c	4.2c	4.0c
LSD (0.05)[3]	NS	0.9	0.7	0.7	0.4

[1]Quality ratings were taken using a 1-9 scale where 1=poor quality and 9=excellent quality.

[2]Plots were water using 25, 50 or 75% of the cumulative 3-day evapotranspiration (ET) rate.

[3]Means in the same column followed by the same letter are not significantly different at the 95% cer tainty level (p=0.05).

Table 2. Visual quality ratings of Tifway bermudagrass in response to different water application rates in Experiment II at Stillwater, OK.

water. Although use of higher salt content water increased these soil test indices, the levels remained relatively low and did not affect Tifway performance.

No significant difference in Tifway visual quality or clipping yield occurred due to watering at 75 rather than 100% ET (all quality ratings were a value of 8). However, Tifway plots irrigated at 75% of ET had statistically greater water use efficiency than plots irrigated at 100% of ET (1.542 vs 1.069 g of clipping dry matter produced per kg of water applied). If these dry matter production values sound small, recall that approximately 99% or more of the water that ever enters a turf plant is lost through evapotranspiration (ET). Additionally, water often accounts for more than 80% of the fresh weight of turf clippings.

It was not surprising that the water use efficiency of Tifway was higher when using the 75% ET replacement water treatments, as no significant increase in clipping yield or visual quality occurred due to adding more water back to the plots by using the 100% ET replacement value. *Special Note:* If the reader uses an ET replacement value for water scheduling, caution should be used in assuming that an ET replacement value of 75% of ET on a 3-day running total will automatically provide the same turf performance for Tifway at all geographical locations. Management inputs, soil and climate are unique at each site and they uniquely affect water use for a specific location.

<u>Experiment II</u>

As in Exp I, the ANOVA procedure revealed that Tifway visual quality, clipping yield and water use efficiency was not affected by water conditioning with the CFWC unit.

As water conditioning did not affect quality ratings, conditioning treatments were pooled and means were separated by watering rate and rating date (Table 2). Not surprisingly, Tifway quality declined as less water was applied as irrigation (Table 2), regardless of whether the water was conditioned or not. Turf visual quality resulting from decreasing irrigation below 75% of ET would not likely be acceptable to the superintendent or golfer.

As water conditioning did not affect yields, conditioning treatments were pooled and means were separated by watering rate and rating date (Table 3). Tifway clipping yield was usually less from treatments that received less water. The water use efficiency of Tifway was greater when irrigated at 25% ET than at 50 or 75% ET (Table 3), however, this water regime provided unaccept-

Watering Treatment (% of ET[2])	Clipping dry matter yield (grams per plot)[1] 8/28/00	9/01/00	9/05/00	9/08/00	9/11/00	9/15/00	9/18/00	9/22/00	WUE[3]
75	38.0a	28a	9.4a	5.9	7.2	8.3a	2.5	1.4	1.05b
50	27.9b	24ab	7.7ab	5.1	6.8	6.3b	2.5	1.5	1.29b
25	27.9b	22b	6.3b	4.9	6.6	6.0b	1.5	1.5	2.50a
LSD (0.05)[4]	8.4	5	2.4	NS	NS	0.7	NS	NS	0.54

[1]Clippings were harvest from a single mowing strip down the center of each plot and dried for 3 days at 49 C before being weighed.

[2]Plots were water using 25, 50 or 75% of the cumulative 3-day evapotranspiration (ET) rate.

[3]Water use efficiency (WUE) is expressed in grams of dry matter produced per kg of water applied per irrigation per plot.

[4]Means in the same column followed by the same letter are not significantly different at the 95% cer tainty level or p=0.05 level.

Table 3. Clipping dry matter and water use efficiency of Tifway bermudagrass in response to different water application rates in Experiment II at Stillwater, OK.

able quality as previously mentioned.

ANOVA testing revealed that neither conditioning of the water with the CFWC unit nor the total amount of irrigation water applied had an effect on the amount of total soluble salts, sodium adsorption ratio, sodium ion, exchangeable sodium percentage, pH or electrical conductivity of the soil.

The differential water quantity treatments containing a high salt load would have been expected to cause a difference in some of the soil test indices over time. This effect failed to materialize. The duration of this study was apparently not long enough to lead to differential amounts of sodium or salinity components to be added to the soil and show up in the soil test results.

Conclusions and Final Suggestions

Use of Carefree Water Conditioner treated water had no effect on Tifway visual quality, clipping yield, water use efficiency or any of the classical soil salinity test parameters in either of two studies conducted at Stillwater, OK in 2000. It is important to recognize that both studies were of very short duration, approximately one month. While this information on product performance is not very promising, it is not known what effects might have resulted had the unit been used in longer term experiments.

It is also important to realize that the Carefree Water Conditioner is only a single example of a non-chemical, catalytic conditioning unit. In fairness to the Care Free Conditioning unit tested, it appears that this research did not test the unit under conditions where the bermudagrass was actually experiencing injury due to super optimal levels of soil salinity or sodium. Additional testing of the unit is needed under conditions where soil salinity and sodium hazard actually materialize to reduce plant growth and substantially alter soil physical and chemical characteristics.

What is very apparent from this research is that use of Care Free Water Conditioning unit conveyed no ability to the turfgrass to overcome the detrimental effects of water deficit stress due to reduced amounts of irrigation water. This was indicated by reduced visual quality and clipping yields when less water was applied, in spite of water conditioning.

Additional water treatment devices that claim utilization of magnetic, electromagnetic and electrochemical conditioning mechanisms are available in the marketplace. Regardless of the product considered for purchase, the prospective buyer is advised to obtain both testimonial and scientifically based performance information or "admissible scientific evidence" regarding the product's performance. It should be the responsibility of product manufacturers and marketers to supply such information to prospective buyers upon request.

Water quality issues at the intended use site should be documented with an irrigation water quality test performed by a qualified lab well in advance of making any product or system purchase. The buyer should make sure that the specific water quality and quantity issues present on-site can be positively affected by the treatment unit before it is purchased. Be aware that there are several factors that degrade water quality. Seek input from knowledgeable agronomists to assist in problem solving. One should become familiar with the mechanisms of irrigation water quality degradation and understand how water quality treatment devices must perform mechanistically in order to correct water quality problems.

Don't forget to get product performance guarantees in writing before purchasing water treatment systems so that a path of recourse is an option should the unit in question not provide the expected performance that was guaranteed in writing.

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Literature Cited

1. Asano, T., R.G. Smith, and G. Tchobanoglous. 1984. Municipal Wastwater: Treatment and reclaimed water characteristics. Pages 2:1-2:26. *In:* Pettygrove, G.S. and T. Asano (eds.). Irrigation with reclaimed municipal wastewater - A guidance manual. Report 84-1 wr. CA State Water Res. Control Board, Sacramento, CA.

2. Ayers, R.S. and D.W. Westcott. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. Food and Agric. Organization of the U.N.

3. Aylward, L. 2002. Florida courses move forward with reverse osmosis plants. *Golfdom* Insider. 30 Oct. 2002. (Available on-line at: http://www.golfdom.com/golfdom/article/articleDetail.jsp?id=35178). Verified: July 10, 2003. (TGIF Record 88898)

4. Care Free Water Technologies (CFWT). 2003. Agricultural Applications. Care Free Water Technologies. Santa Ana, CA (Available on-line at:http://www.carefreewater.com/agricultural.cfm). Verified July 10, 2003.

5. FEMP. 1998. Non-chemical strategies for scale and hardness control. Federal Technology Alert. Federal Energy Management Program, US Dept. of Energy. Report EE-0162. (out of print).

6. Gale, J., R. Koenig, and J. Barnhill. 2001. Managing soil pH in Utah. Pub. Ag-So-07. Utah Coop. Ext. Service. Utah State Univ. Logan, UT.

7. Harivandi, A., A. Terry, and M. Yates. 1994. Wastewater quality, treatment and delivery sys-

tems. Pages 105-171. *In:* Wastewater Reuse for Golf Course Irrigation. Lewis Publishers. Chelsea, MI. (TGIF Record 29970)

8. Howard, H. F. 2000. Acidify irrigation water to lower soil pH. *Grounds Maintenance* April, 2000. (http://grounds-mag.com/ar/grounds_maintenance_acidify_irrigation_water/index.htm). (TGIF Record 65910)

9. Kizer, M. 2003. Oklahoma evapotranspiration model. Mesonet Premium Subscribers. University of Oklahoma. Norman, OK. (available on-line at: http://www.mesonet.ou.edu/premium/agmodels.html?evapotranspiration). Verified: July 10, 2003.

10. Lower, S.K. 2003. Goofy water-treatment pseudoscience and products. Junk science in the marketplace. Burnaby, BC. Canada. (Available on-line at: http://www.chem1.com/CQ/ aquacrack .html). Verified: July 10, 2003.

11. The Good Water Company (TGWC). 2003. Care Free. The Good Water Company. Wichita, KS. (Available on-line at: http://www.goodwaterco.com/r-carefree.html) Verified: July 10, 2003.

12. West, B.A. 2002. Non-chemical conditioning of water. Nelson Environmental Technologies, Inc. McAllen, TX. (Available on-line at: http://nelsonenvironmentaltechnologies.com). Verified: July 10, 2003.