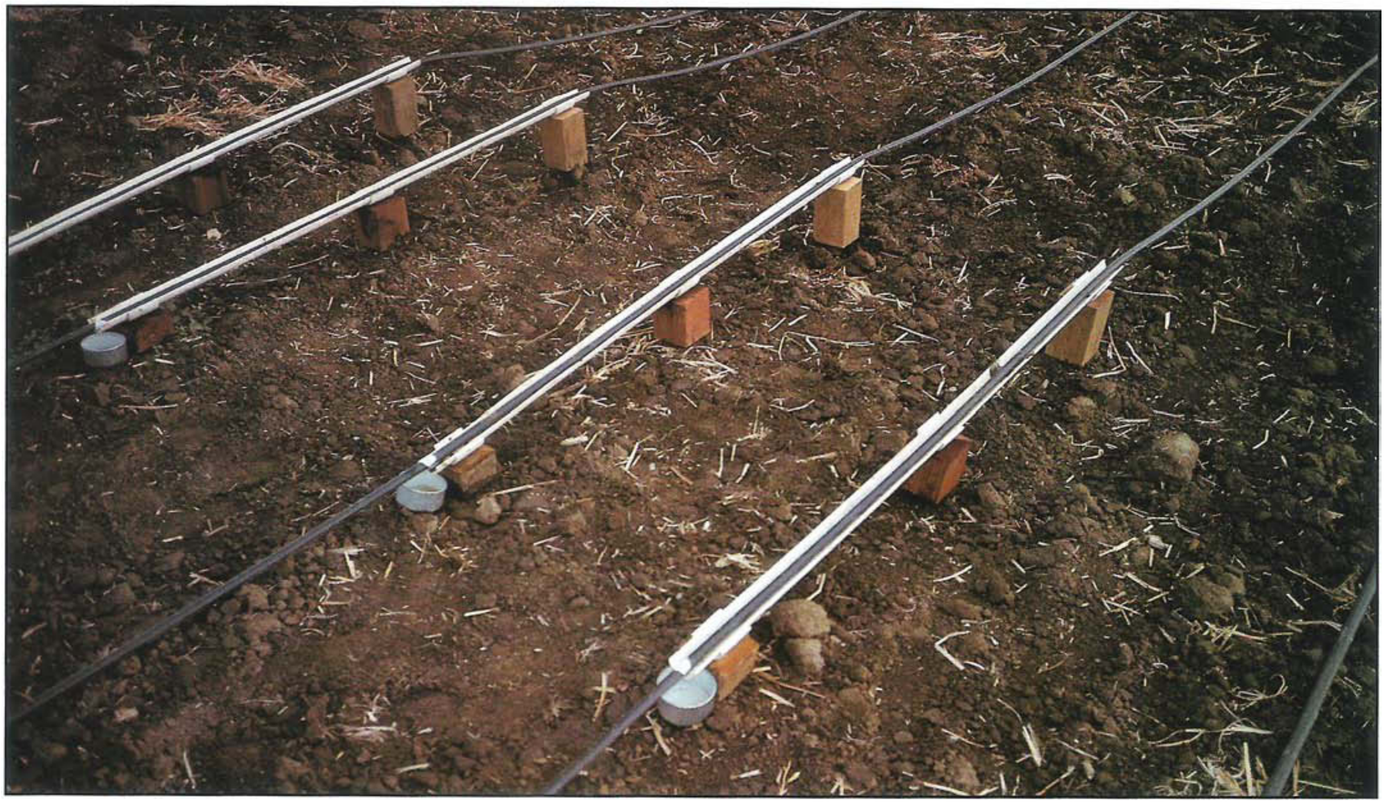

In laboratory and field tests . . .

Water conditioners fail to improve infiltration or prevent clogging

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Three devices that physically treat irrigation water were tested in the laboratory and the field. Results of these experiments indicate these water conditioners were ineffective in increasing the infiltration rate of water into the soil or in preventing calcium carbonate precipitates from clogging drip emitters under the conditions in which they were tested.

Specific chemical treatments of water have improved its suitability for agricultural, industrial, and domestic uses. Adding calcium sulfate (gypsum) to irrigation water low in electrolytes sometimes increases water infiltration. Water softeners that work on the principle of ion exchange are used widely to prevent precipitate buildup of calcium and magnesium carbonates in domestic and industrial equipment, pipes, and fixtures. Although effective, these chemical treatments are costly.

California's ongoing drought and the consequent need for water conservation have resulted in the marketing to farmers of water-treatment devices that allegedly increase irrigation water use efficiency. These devices physically treat water, but they do not change its chemical composition. Although the mechanisms by which this occurs are unclear, certain manufacturers have claimed that the physical treatment can reduce or prevent precipitation buildup of calcium and magnesium carbonates in irrigation hardware. Chemical precipitate clogging by calcium carbonate

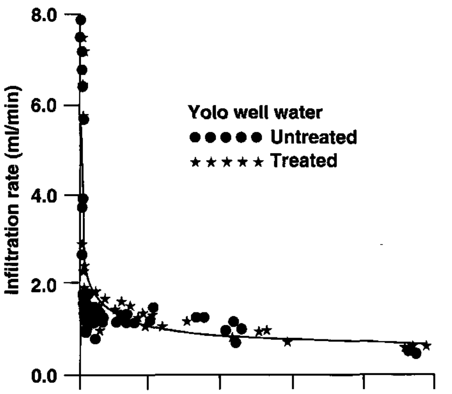
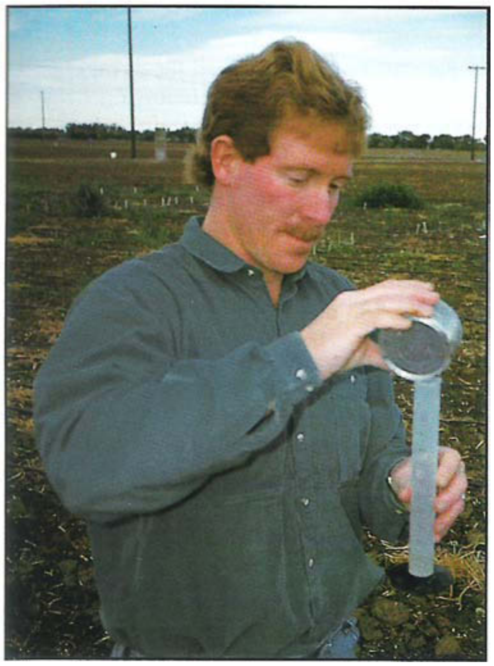


Fig. 1. Treatment of irrigation water did not influence infiltration rate when plotted as a function of time.



Above, water collected during monitoring of drip tape is measured.

At left, a PVC trough is used to collect discharge from a 5-foot section of drip tape.

(lime) is a major problem facing low-volume irrigation system users, particularly those utilizing well waters. Water sources with a calcium level of 2 milliequivalents per liter (meq/l) or higher with a comparable level of bicarbonate and a pH equal to or greater than 7.5 are candidates for lime precipitation problems.

Some manufacturers of physical water-treatment devices claim their products can improve water infiltration and salt leaching. Because acquisition and maintenance costs of treatment devices are relatively low, water conditioners are an attractive alternative to improve irrigation water management. However, there have been no scientific tests showing the benefits of these water conditioners in agriculture. Here, we report results of testing three of these water conditioners. Mention of company names or products is for the benefit of the reader only and implies no endorsement by the authors or their institutions. The results reported reflect only those under the conditions in which the products were tested.

Three devices tested

Of the three devices field tested to study the effects of conditioned water on chemical clogging of drip-irrigation emitters, two were magnetic conditioners - an in-line device (Aqua-Flo Inc.) and a clamp-on device (Soft-Strap). Magnetic conditioners come in different sizes, depending on water-flow rate and pipe size. Physical treatment consists of imposing a magnetic field across flowing water to induce spatial orientation changes of ions and polar molecules in the water. Magnetic treatment effects, reportedly temporary, last a maximum of 72 hours. These two devices are marketed primarily for their benefits in reducing or preventing scale formation and calcite accumulation in boilers, pipes, and plumbing fixtures. We tested them to assess their potential in reducing or preventing chemical clogging of drip-irrigation emitters.

The third device, distributed by various companies, is the Care-Free water conditioner. A self-contained unit consisting of a brass casing, it is installed in the main water line. Irrigation water is allegedly conditioned by electron exchange between the water and the grounded core of the water conditioner. Different sizes are available, depending on flow rate.

The conditioned water, it is claimed, has a reduced surface tension, thereby increasing water infiltration while simultaneously improving salt leaching. To investigate the claim that treated water improves water infiltration, controlled laboratory studies using soil columns were conducted. Furthermore, it was claimed that using the Care-Free conditioner would reduce chemical precipitation of calcium carbonate in drip-irrigation lines. We also tested these devices in a drip-irrigation field experiment using water with added salts.

Infiltration tests

In consultation with the distributing company, we installed a 1.5-inch (3.8-cm) Care-Free water conditioner in the water discharge line of the UC Davis campus domestic water supply and in the discharge line of a 200-foot-deep well at UC's Campbell Tract Research Facility. These water supplies had salinities of 0.55 (tap water) and 1.0 deciSiemens per meter (dS/m) (well water), corresponding to 352 and 640 mg/l (ppm) total dissolved solids (TDS). As specified in the installation instructions, the conditioner was grounded with copper wire and the outflow rate was approximately 250 gallons per minute (gpm). This outflow rate was within the optimum range recommended for the 1.5-inch conditioner. Water was treated 1 to 2 days before it was used in the laboratory for infiltration tests.

The Care-Free water conditioner was tested on three Tulare clay soils with soil saturation extract salinities (EC_e) of 1.0 (621 ppm), 1.4 (902 ppm), and 1.8 (1152 ppm) dS/m, respectively; and a Yolo clay loam with an EC_e of 1.5 dS/m. Columns of 3.9-in. (10-cm) height and 3.3-in. (8.5-cm) inside diameter were filled to 1.56 in. (4 cm) below the rim with disturbed, 0.08-in. (2-mm) sieved soil material to a constant soil bulk density. Four soils treated with four different water treatments, each replicated three times, resulted in 48 infiltration tests.

Rather than field-test the Care-Free water conditioner (where spatial variability of water infiltration into the soil is present and uncontrollable), we chose to compare infiltration tests with treated and untreated water under controlled laboratory conditions. Using disturbed soil material in uniformly packed soil columns minimized infiltration variability between treatments. Experiments were cautiously conducted to avoid bypass water flow between the soil and column walls which can occur after ponding water on the soil surface. The soils expanded after wetting, thereby closing air gaps existing before the infiltration measurements.

The constant head infiltration rate was measured for these initially dry soil columns as a function of time during a 24-hour period. During infiltration, cumulative drainage was measured, and subsamples of the drainage water were analyzed for salinity at various times within the 24 hours. Columns were weighed before and after the infiltration test. From the difference in mass, we computed the soil volumetric water content at

TABLE 1. Final infiltration rate (i_f, ml min^{-1}) and cumulative drainage (D,ml) as measured from triplicate soil samples*

Treatment	Yolo tap		Yolo well		Tulare–621 tap		Tulare 621–well	
	i_f	D	i_f	D	i_f	D	i_f	D
Untreated*	0.56	321	0.97	240	0.03	25	0.03	30
Treated	0.6	261	0.82	290	0.03	30	0.03	31
	Tulare-902 tap		Tulare–902 well		Tulare–1152 tap		Tulare-1152 well	
	i_f	D	i_f	D	f	D	i_f	D
Untreated	0.02	20	0.03	37	0.02	–	0.015	7
Treated	0.03	28	0.03	36	0.02	5	0.015	6

*Differences between all treatments were statistically insignificant.

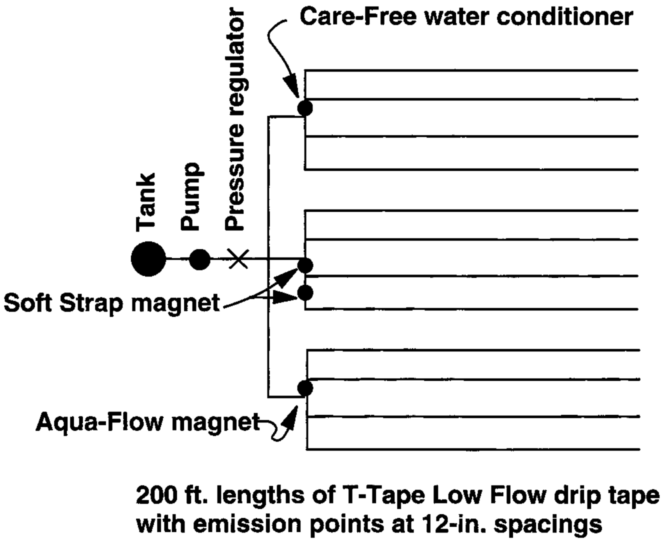


Fig. 2. All three physical treatment devices were included in experimental design of drip irrigation field tests.

the end of the 24 hours. In addition, the soil columns were allowed to drain for 1 day and were reweighed to obtain the volumetric water content after 24 hours of drainage. At the conclusion of the infiltration test, a subsample of the soil was analyzed for salinity.

Figure 1 shows the results of all replicate infiltration tests with well water for the Yolo soil. Data of all soils and treatments showed a rapid decrease in infiltration rate, approaching steady state after approximately 300 to 600 minutes. For all four soils and both water qualities, we found no significant difference in infiltration rate between treated and untreated waters. The solid line in figure 1 represents the best fitted lines for both untreated and treated irrigation water. Moreover, table 1 data indicate that no significant differences in final infiltration rate (i_f, ml min^{-1}) or cumulative drainage (D, ml) were observed between columns receiving treated and untreated water for all four soils and two water qualities. Because drainage volumes between conditioned and unconditioned water treatments were equal, infiltrated water (ml) totals in both treatments were equal as well. Table 1 values are average values computed from the triplicate infiltration tests.

In general, standard deviations were large with respect to the difference in mean values. Therefore, differences between mean values were statistically insignificant in all cases. We conclude that conditioning the water under these experimental conditions does not appreciably affect the water infiltration rate or cumulative infiltration, nor does it improve leaching. The latter can be concluded from insignificant differences in drainage volumes. In addition, average soil salinities as determined from saturation extracts after the infiltration tests were not different between treatments. Drainage water salinities were not significantly different between treated and untreated irrigation water.

TABLE 2. T-Tape discharge rates (GPH/100 ft) for irrigation treatments and for measurement dates*

	Measurement date		
Treatment	8/17/90	11/20/90	1/23/91
Care-Free device			
Treated	13.0a	11.4b	11.2b
Control	13.2a	11.8b	10.8b
Soft-Strap magnet			
Treated	13.3a	11.0b	9.6b
Control	13.2a	12.0c	11.6c
Aqua-Flo in-line magnet			
Treated	12.4a	11.2b	10.6b
Control	12.2a	11.2b	10.9b

*Flow rates from treated and control lines were statistically compared for each device separately. No attempt was made to compare flow rates between different devices.

Finally, we also measured the change in volumetric water content following 1 day of free drainage after the 24 hours of infiltration. These data indicated that water conditioning had no statistically significant effect on soil-water retention.

Although we investigated two different sources of water, their salt concentrations were relatively close. One might argue that conditioning irrigation water of higher salinity content would have increased beneficial effects. However, it is expected that water with higher salinities than used in this experiment would enhance, rather than further decrease, infiltration, as soil dispersion effects are alleviated in sodium-containing soils.

It has been claimed that the Care-Free water conditioner reduces the surface tension of water, while simultaneously increasing soil-water retention. These two claims contradict each other; a lower surface tension of water decreases soil-water retention.

Field experiments

As mentioned, certain water conditioners reportedly reduce calcium carbonate precipitation in treated waters. If these physical devices are effective in commercial and industrial uses, they may also be effective in low-volume irrigation systems. A field experiment was designed and installed to make a side-by-side comparison of the performance of irrigation-drip tape supplied with treated and untreated water.

The experimental design of the field test is shown in figure 2. The drip tape chosen for investigation was T-Tape Low Flow with 12-inch (30-cm) emission point spacing. This is a turbulent flow drip tape commonly used for both surface and subsurface applications. Twelve, 200-foot (61-m) lengths of T-Tape were laid out on a nonvegetated soil surface and connected to a manifold so that each water-treatment device being investigated could be operated separately. For each water conditioner tested, two drip-tape lines were supplied with treated water and two drip lines were supplied with untreated water (control lines).

The water supply for the experiment was the UC Davis domestic well water with calcium and bicarbonate levels of 1.3 and 4.2 meq/l, respectively, and a pH of 7.9. To increase the likelihood of chemical precipitation, the source water was placed in a 400-liter tank and quantities of calcium chloride ($CaCl_2$), sodium bicarbonate ($NaHCO_3$), and magnesium sulfate ($MgSO_4$) were added to increase the calcium, bicarbonate, and magnesium levels by 3 meq/l, 3 meq/l, and 1 meq/l, respectively. One tank of this spiked irrigation water was used for each irrigation where one-third of the water in the tank was sequentially directed to each of the three treatment pairs. Pressure for system operation was supplied by a small pump and controlled through a pressure regulator to maintain pressure at the head of the manifolds at 9 psi (pounds per square inch). A screen filter was installed in the system to ensure that particulate matter did not enter the system and contribute to emitter clogging. Periodically, sodium hypochlorite (bleach) was added to the system to eliminate any potential for emitter clogging by organic materials (that is, slimes or algae).

Initial drip-tape flow rates, taken August 17, used the UC Davis water with no salt additions (unspiked). Flow rate measurements were taken by laying the drip tape in a 5-foot section of 1.5-inch PVC pipe split in half lengthwise. This trough collected water from five emitter openings and delivered it into a container for measurement. Discharge was collected for 1 minute. Measurements were taken at 50-foot increments along each of the 12, 200-foot lengths of drip tape. Each measurement site was marked to facilitate remeasurement later.

Table 2 lists the average flow rates for each of the six treatments. For each treatment device, there was no statistical difference (using a two-sample analysis utilizing a T-test hypothesis technique at a 5% level) between quantities of water discharged from the control lines (no treatment device) and the treated lines. Flow rates were lower for the Aqua-Flo in-line magnet treatment and control than for the other four treatments. This was the result of a pressure loss across the magnet's small-diameter passageway. A small metallic pipe of equal length and diameter was placed in the in-line magnet-control treatment to create the same pressure loss and to allow for a valid comparison between treated and untreated water.

From August 17 to August 29, 1990, four irrigations were done using UC Davis water with the previously mentioned levels of added calcium chloride, sodium bicarbonate, and magnesium sulfate. On August 29, when drip-tape flow rates were taken, no significant reductions in discharge rates were found, indicating that no clogging had occurred in either treated or untreated lines. Concentrations of calcium chloride, sodium bicarbonate, and magnesium sulfate were doubled thereafter to increase the likelihood of chemical precipitate clogging. From September 5 to November 20, 1990, UC Davis water, spiked with double the amount of added salts, was used in 13 irrigations.

On November 20, flow rates were measured on each of the 12 drip lines at the same locations monitored previously (table 2). A comparison between drip-tape flow rates measured on August 17 and November 20 indicated that decreases in flow rates were statistically significant for all but the Aqua-Flo in-line magnet-control treatment. The decrease in average flow rate from August 17 to November 20 was not statistically significant at the 5% level because of a large variability in measured flow rates. Statistical analysis of the November 20 flow rates indicated no difference in drip-tape flow rates between the control and treated lines for the Care-Free device and the Aqua-Flo in-line magnet device. The control and treated lines for the Soft Strap magnet differed significantly, with the average flow rate higher for untreated control lines than for treated lines. It is unclear why untreated lines had a higher average flow rate.

Irrigations with synthetic irrigation water containing double amounts of added calcium chloride, sodium bicarbonate, and magnesium sulfate were continued nine more times between November 20, 1990 and January 23, 1991. Final drip-tape flow measurements were taken January 23 (table 2).

Flow rates measured January 23 were less than those taken November 20, indicating that precipitate clogging continued to increase. This decrease from the initial drip-emitter discharge rate was statistically significant for all but the Aqua-Flo in-line magnet-control treatment. This treatment showed an 11% decrease in average flow rate during the experiment, but the high variance among the collected flow rates prevented the decrease from being statistically significant at the 5% level. As with measurements taken November 20, the January 23 drip-tape flow data indicate no statistically significant differences between controls and treated lines for either the Care-Free or Aqua-Flo in-line magnet devices. For the Soft Strap magnet, average flow rate was higher for untreated control lines than for treated lines. It is again unclear why untreated lines would have a higher average flow rate, but it is possible that some scale formation inside the treated drip lines had dislodged, thereby contributing to emitter clogging.

The field experiment's reduced drip-tape emitter discharge rates suggests that chemical precipitate clogging (calcium carbonate) was occurring in all treatments. Statistical analysis indicated that no treatment device tested effectively prevented precipitate clogging under test conditions. The levels of calcium and bicarbonate evaluated were high enough to ensure that precipitate clogging by calcium carbonate occurred in control lines. The effects of the treatment devices on irrigation waters with lower calcium and bicarbonate levels, which could pose a chemical precipitate hazard over a long period, were not investigated.

To reduce or eliminate precipitate clogging, residual effects of treatment devices must be maintained during the water's "residence" time in the drip-irrigation system. It is likely that chemical precipitates form when the irrigation system has been shut down and the residual water left in drip lines is subjected to prolonged high temperatures as a result of exposure to sun. Evaporation of water in the lines could lead to increased concentrations of precipitate-causing constituents. The resulting precipitates could be moved into the emission paths the next time the irrigation system is operated, resulting in clogging. Some drip systems may be operated daily; others may be operated less frequently with one or two irrigations per week not uncommon. The residual effects of the treatment devices would need to be long lasting to prevent such an occurence.

Conclusions

Laboratory experiments were carried out with irrigation water with salinities of 352 and 640 ppm. Soils treated were a Yolo clay loam and three Tulare clay soils with different soil salinity concentrations. Experiments showed no significant effect of the Care-Free water conditioner on soil-water infiltration rate, soil leaching, and soil-water retention. Our test results pertain to the influence of the Care-Free water conditioner on soil and soil–water characteristics only.

Field experiments were conducted to test the effectiveness of three water conditioners (Care-Free water conditioner, Aqua-Flo in-line magnet, and Soft-Strap magnet) in maintaining drip-irrigation emitter-discharge rates by avoiding chemical precipitate formation. Synthetic irrigation waters were prepared that were supersaturated with calcite. Emitter discharge rates decreased over time and all water conditioners tested were ineffective in maintaining maximal discharge rates.

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