Soluble calcium compounds may aid low-volume water application

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Ann Wildman adds a concentrated calcium salt solution to an intravenous bag, which feeds a measured amount of calcium to irrigation water flowing into the PVC infiltrometer at bottom. Experiments showed that addition of calcium doubled or tripled the water infiltration rate over that of untreated low-salt water.

Slow water infiltration is a serious problem in some orchards and vineyards on the east side of the San Joaquin Valley. It is often associated with irrigation water low in salt and soils with inherently slow infiltration rates. Gypsum, a calcium salt, is commonly used to improve water infiltration in nonsodic soils. It is the most effective with low-salinity irrigation water (electrical conductivity [EC] < 0.1 decisiemens per meter [dS/m]).

When infiltration drops below about a tenth of an inch (0.25 cm) per hour, it is difficult to get enough irrigation water into the root zone to satisfy the needs of the tree or vine. Water stress often becomes evident by June, increasing in severity as the evaporative demand peaks in July and August. A winter irrigation to supplement rainfall and maximize soil water storage in the root zone can help reduce the severity and duration of stress in summer.

Low-volume irrigation systems (drip, fogger, micro-sprinkler) are now commonly used in permanent crops. Slow water infiltration can be more serious with these than with conventional irrigation methods, since low-volume irrigation wets less surface area. Also, it is difficult to distribute gypsum only to the wetted soil around an emitter, and gypsum applied directly to irrigation water can cause plugging of emitters.

The objective of our research was to increase water infiltration in a drip-irrigated citrus orchard. We applied soluble calcium compounds and other amendments either to the irrigation water or to the soil. The experiment was conducted in a mature navel orange block at the University of California Lindcove Field Station in Tulare County. The soil was a San Joaquin sandy loam with steady-state infiltration of less than a tenth of an inch (0.25 cm) per hour. Irrigation was with canal water that had an electrical conductivity (salinity) of 0.1 dS/m.

Test methods

The orchard was drip irrigated every weekday to meet tree requirements. Each tree had five drippers (1 gallon per hour) to which a length of quarter-inch tubing was attached. The experimental design was a randomized complete block with nine treatments and eight replications; 72 infiltrometers were installed.

An infiltrometer consisted of a 12-inch-diameter PVC pipe placed near each dripper and driven about 3 inches into moist soil, leaving 4 inches above the surface. We placed the dripper tubing so that water would be applied inside the infiltrometer. Half-inch holes drilled in the PVC pipe at the soil surface allowed surface spreading unimpeded by the infiltrometer. When measurements were made, these holes were stoppered; the water quickly filled the infiltrometer, spilling out of an outlet near the top. We calculated the infiltration rate from the difference between inflow from the dripper and outflow from the infiltrometer.

Some treatments required a continuous application of 3 milliequivalents per liter (meq/L) of calcium to irrigation water. We applied the amendment through intravenous (IV) bags and tubing, filling the bags daily and adjusting the flow rate. The discharge tube from the IV bag was attached to the discharge tubing from the dripper.

1986 Lindcove experiment

Treatments were as follows: a 250 ppm polyacrylamide solution applied once to treat a 2-inch soil depth; gypsum applied weekly to maintain a slight excess; nonionic surfactant added weekly at a rate of 1 quart per acre; calcium nitrate continuously applied to irrigation water to add 3 meq/L. Amendments were added to both disturbed (cultivated 2 inches deep) and undisturbed soil.

We have grouped averages of the weekly infiltration rates over two periods—eight weeks during daily or weekly addition of amendments, and five weeks following cutoff of the amendments (table 1). Calcium treatments were significantly higher than most noncalcium treatments over the first time period. However, the calcium nitrate treatment dropped rapidly after the cutoff, while the gypsum treatments remained higher because of a buildup of excess gypsum from the weekly additions. In this experiment, gypsum was the standard reference for improving infiltration by low-salt water. We applied excess gypsum to ensure that the supply did not run out while we were adding other amendments.

During addition of the amendments, from June 11 to August 5, there were no significant differences among the three calcium treatments (with one exception). We have averaged and plotted them as a single line, with an average infiltration rate of 0.42 cm (about 1/6 inch) per hour (fig. 1). During this time, there were also no significant differences among the noncalcium treatments, including the control. We therefore averaged and plotted them as a single line, averaging 0.24 cm (less than 1/10 inch) per hour over the same period. The calcium treatments produced a trend of increasing infiltration rates while they were added; the noncalcium treatments, if anything, trended lower during the season. There were no consistent differences between disturbed and undisturbed treatments.

After cutoff, the calcium nitrate infiltration rate dropped rapidly (plotted separately from gypsum in fig. 1) and its difference from non-calcium treatments became insignificant. We were not able to discern any favorable effect on infiltration by the noncalcium amendments.

1987 Lindcove experiment

The favorable results with calcium nitrate, and the ease of preparing and applying it to irrigation water, suggested further study of other easily soluble calcium compounds. In 1987, we compared calcium nitrate with calcium chloride, calcium acetate, and calcium ammonium nitrate (CAN-17, a commercial liquid fertilizer containing 17% nitrogen). Each was added continuously to irrigation water in separate rings at 3 meq total salt per liter. Amendments were added from June 20 through August 19; irrigations were five days each week for six hours a day.

In two other treatments, we batch-added 10 times the daily amounts of calcium nitrate or CAN-17 before every tenth irrigation during the same period. These additions were made the day before a regular infiltration measuring day. In two other treatments, single applications of calcium nitrate or CAN-17 equaling 30 pounds of nitrogen per acre were added at the beginning of the experiment.

TABLE 1. 1986 Lindcove treatments and grouped average infiltration rates

Treatment	Avg infiltration rate — Amendments — Applied 6/11 - 8/6	Not applied 8/13 - 9/17
	cm/hr	*cm/hr*
Calcium nitrate, undisturbed	.46 a	.30 bc
Gypsum, disturbed	.42 a	.39 ab
Gypsum, undisturbed	.37 ab	.52 a
Polyacrylamide, disturbed	.29 bc	.19 cd
Polyacrylamide, undisturbed	.29 bc	.18 cd
Control, disturbed	.26 bcd	.21 cd
Control, undisturbed	.23 cd	.19 cd
Nonionic surfactant, undisturbed	.21 cd	.18 cd
Nonionic surfactant, disturbed	.16 d	.09 d
LSD .05	.12	.13

Over the 10 weeks they were applied, the daily and bi-weekly CAN-17 treatments each added 58 pounds of nitrogen per acre. The daily calcium nitrate treatment added 43 pounds nitrogen per acre.

The ninth treatment was a control, and there were eight replications. We therefore reused the same 72 rings, still in place since 1986, after cleaning them out and cultivating the soil inside. We measured infiltration twice before applying treatments, to ensure that there would be no carryover effect from 1986. Statistical analysis based on the 1986 treatments showed no significant differences. The rings were then ranked in order of increasing infiltration rate, and divided into eight blocks of similar rates. Replications of nine treatments each were randomized within these blocks.

Among daily treatments, calcium acetate and calcium nitrate had significantly higher infiltration rates than the control, both during and after the time they were added (table 2). Calcium chloride and CAN-17 rates were higher than the control while they were added, but not quite significantly at the 5% level. Still, we believe these amendments had a beneficial effect on infiltration.

Bi-weekly calcium nitrate had a seesaw effect (not shown). It gave a significantly higher infiltration rate during the weeks it was added but dropped to near the control on the alternate weeks, hence the intermediate average infiltration of 0.35 cm per hour. All other treatment averages ranged from 0.23 down to 0.13 cm per hour during the same eight weeks.

We found that the infiltration rates were grouped into three general levels, each significantly different from the other two on most dates (fig. 2). Following the August 19 cutoff, average rates for all daily treatments dropped considerably. A carryover effect on soil structure, however, allowed their infiltration rates to remain significantly higher than those of bi-weekly, single-application, or control treatments.

In addition to the differences in infiltration rate, there were striking differences in the pH and exchangeable calcium of soil samples taken three weeks after daily amendment additions stopped. Calcium acetate (daily) averaged one pH unit higher than the control (table 3). All calcium nitrate and chloride treatments were almost a half unit higher than the control. The three CAN-17 treatments, however, ranged from 0.5 to 1.3 pH units lower than the control.

Exchangeable calcium values closely paralleled the pH values. The higher pH for the calcium acetate treatment may result from rapid microbial metabolism of acetate, producing bicarbonate that raises the pH. This process also could raise cation exchange capacity (CEC) as a pH-dependent charge. We did not measure CEC, but the higher exchangeable calcium in the calcium acetate treatment may partly result from increased CEC, as well as from the expected replacement of other cations by calcium. Continued use of calcium acetate could eventually precipitate calcium carbonate. We assume the lower pH and exchangeable calcium in the three CAN-17 treatments resulted from acidification by the ammonium in CAN-17. The acidification apparently had a greater influence on these characteristics than did the calcium in the compound.

All of the calcium materials added daily could be economical under some circumstances. Calcium nitrate and CAN-17 are more expensive than some nitrogen sources, but improving water infiltration along with supplying the crop's nutritional needs could make these amendments cost-competitive. Calcium chloride should be inexpensive enough, and adding chloride ion at 3 meq/L should not harm most crops growing in unrestricted soil profiles. Calcium acetate appears to be an ideal choice, if it can be produced cheaply and in quantity. The anion is not likely to have detrimental effects, whereas nitrate or chloride anions in excess could harm plant growth or cause groundwater pollution. A major company is now producing a by-product mixed calcium-magnesium acetate with a potential use as a highway de-icer.

A concern with using either calcium nitrate or CAN-17 is whether improved water infiltration might come at the expense of over-fertilization or improper timing of nitrogen application. Possible consequences would be uneconomic fertilizer use or environmental pollution. At 3 meq/L of total salt added, calcium nitrate and CAN-17 provide 124 and 168 pounds nitrogen per acre-foot of water, respectively. Some crops require 200 or more pounds of nitrogen per acre per year. There is also evidence that fertilization in summer is at least as beneficial as in other seasons. However, we did not study the fertility or environmental implications of continuous low-rate nitrogen additions. These questions should be addressed in future investigations.

TABLE 2. 1987 Lindcove treatments and grouped average infiltration rates

	Avg infiltration rate	
	Amendments	
Treatment	Applied 6/24 - 8/19	Not applied 8/26 - 9/8
	cm/hr	*cm/hr*
Calcium acetate, daily	.68 a	.31 ab
Calcium nitrate, daily	.52 ab	.37 a
Calcium chloride, daily	.41 bc	.28 abc
CAN-17, daily	.40 bc	.22 bcd
Calcium nitrate, biweekly	.35 bcd	.18 bcde
Calcium nitrate, single application	.23 cde	.12 de
Control	.22 cde	.18 cde
CAN-17, biweekly	.17 de	.07 e
CAN-17, single application	.13 e	.09 e
LSD .05	.20	.12

TABLE 3. Soil analyses following 1987 experiments; pH and exchangeable calcium (X-Ca) of nine treatments, three replications

Ranked treatments	pH, 0-15 cm	Ranked treatments	X-Ca, 0-15 cm
Calcium acetate, daily	7.30 a	Calcium nitrate, daily	11.07 a
Calcium acetate, daily	6.87 ab	Calcium nitrate, daily	8.30 b
Calcium nitrate, sgl app	6.73 bc	Calcium nitrate, sgl app	7.87 bc
Calcium chloride, daily	6.73 bc	Calcium nitrate, biweekly	7.80 bc
Calcium nitrate, biweekly	6.70 bc	Control	7.73 bc
Control	6.33 c	Calcium chloride, daily	7.13 bcd
CAN-17, daily	5.80 d	CAN-17, daily	6.47 cd
CAN-17, biweekly	5.30 e	CAN-17, biweekly	5.83 d
CAN-17, sgl app	5.03 e	CAN-17, sgl app	5.73 d
LSD .05	0.47		1.49

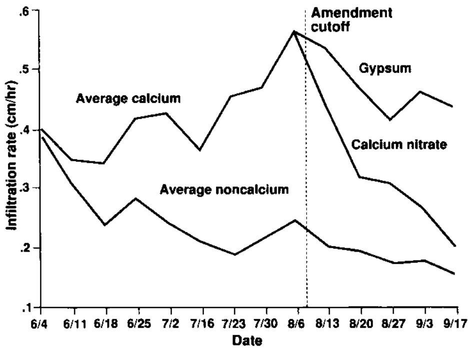

Fig. 1. Before amendment cutoff, the average infiltration rates of three calcium treatments were significantly higher than the average of noncalcium treatments. After amendment cutoff, the calcium nitrate rate, shown separately from the gypsum, dropped rapidly.

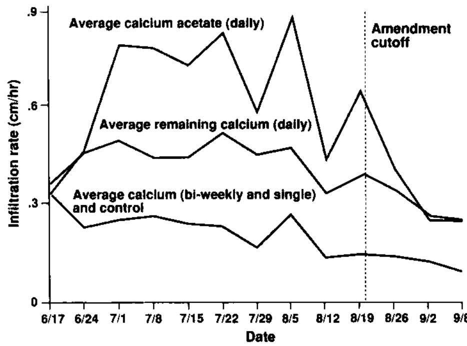

Fig. 2. Daily calcium acetate gave significantly higher infiltration rates (0.7 cm/hr) than average of daily calcium nitrate, CAN-17, and calcium chloride (0.44 cm/hr). Combined average of bi-weekly and single applications of calcium nitrate and CAN-17, plus the control, was significantly lower (0.22 cm/hr) than all daily treatments.

Conclusions

These experiments confirm our hypothesis that soluble calcium compounds, added continuously in the irrigation water, can double or triple the infiltration rate over that of untreated low-salt water. There is also strong evidence that occasional additions of calcium nitrate or CAN-17 are not effective in maintaining high infiltration rates. The pH increase with calcium acetate suggests that this salt could be used to compensate for the acidifying effects of nitrogen fertilizers injected into drip systems, while improving water infiltration.

We also found preparing and adding concentrated calcium solutions to drip-irrigation systems to be practical. Rates of 120 gallons of a concentrated solution of calcium nitrate or chloride or 80 gallons of CAN-17 will add 3 meq/L to an acre-foot of water. About 400 gallons of calcium acetate solution would be required because of the somewhat lower solubility of that salt. In contrast, it would take 35,000 gallons of a saturated gypsum solution to add the same 3 meq/L to an acre-foot of water.

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