drip-irrigated processing tomatoes as this crop-water management practice is studied further.

Grower adoption

There are several concerns related to adopting subsurface drip irrigation to control weeds.

First, growers are uneasy about not being able to visually determine if their irrigation system is working properly. The system has to be designed so that line pressure can be monitored.

Second, the initial costs of materials (such as line, filtration units, and fittings) and installation are high. Individuals who use this system, however, claim that costs are offset in subsequent years by reduced traffic demands in the field and labor savings. Buried drip tubing should last for several years.

Third, the system requires careful management to avoid problems with filtration, orifice clogging, leaks, and the like.

Fourth, the depth and spacing of the tube must be determined for each situation according to soil type, slope, cropping sequence, and equipment. It would be desirable to bury the tape or tubing deep enough in row crops to avoid cultivation damage but shallow enough to subirrigate without using large quantities of water, particularly early in the season. Furthermore, sequential crops must accommodate a fixed spacing of buried drip tubes. This may require changes in cultural practices.

Conclusion

Irrigation management can play a large role in the control of annual weeds in summer crops. In this experiment, subsurface drip irrigation without herbicides was at least as effective in controlling weeds as herbicides under sprinkler and furrow irrigation.

At present, this irrigation method as an ecologically sound alternative for controlling weeds would be most attractive to small growers who produce crops without pesticides or by transitional growers moving from strong to reduced chemical dependence.

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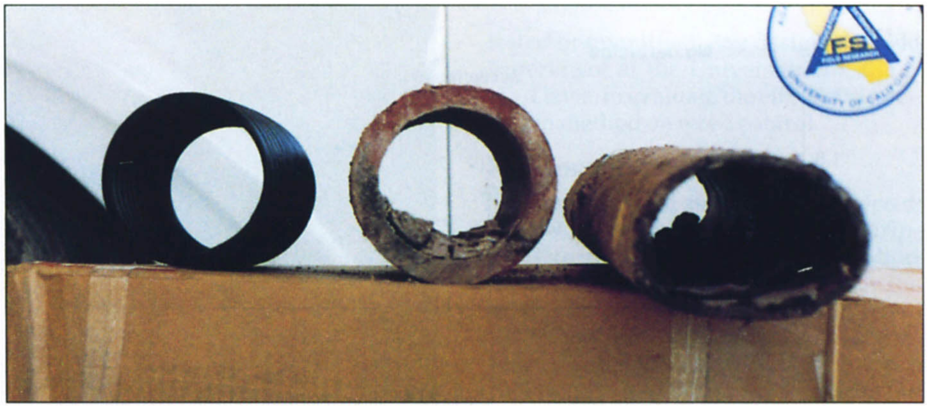
The authors extend their appreciation to Inge Bisconer of Hardie Irrigation for donation of the drip irrigation material and to Brenda Lanini of Campbell Soup for donation of the tomato seeds. They also thank Kent Kaita, Wilbur Bowers, Lee Smith, Jeff Mitchell, and Alan Dong for their assistance.



New plastic drain (left) compared with excavated clay and bituminous fiber drains installed in 1964.

Drainage system performance after 20 years

Mark E. Grismer ❑ Ian C. Tod ❑ Frank E. Robinson

As part of a study of the longevity and effectiveness of clay, bituminous fiber, and concrete drainage pipes, several pairs of these pipes were installed in a heavy clay soil at the Imperial Valley Agricultural Center at El Centro, California in January 1964. Drain lines were laid at a depth of 7 feet and a spacing of 120 feet. Bituminous-fiber drains were installed in a fiberglass envelope; washed gravel was used to enclose the clay and concrete pipes.

Observations on the effectiveness of the three materials were begun in the spring of 1966 by University of California researchers Frank E. Robinson and James N. Luthin. They found no real difference in the performance of the different pipe materials and reported that variability in drain water discharge and quality was due primarily to variability of soil water transmission properties, especially along the trenches made during drainline installation (*California Agriculture*, August 1968).

Though one of the original intents was to study the effectiveness of these "lines...periodically to show how flow changes with time," drain discharge measurements were discontinued until recently. Also, periodic examination of drainline "segments...to see how they stand up under a long period of use" was part of the original study.

Over 20 years have elapsed since the subsurface drain discharge and drain water salinity were originally measured. We investigated the performance of the old drainage system, comparing it with a newly installed system, and examined the status of the original drainline materials as part of a larger study related to infiltration and drainage of cracking clay soils. This investigation was conducted to address some of the concerns of the original study.

Field description

We conducted our study on the heavy clay quarter of the field used in the original trial. The area was tiled with two bituminous fiber and one clay drainline. Drain discharge and water quality were measured on the three drainlines following irrigation during the spring and summer of 1986 and 1987.

In June 1987, three new corrugated plastic drainlines were installed with gravel envelopes. The new drains were placed within 10 feet of the old drains. To eliminate effects of the old drains on performance of the new ones, the old drains were partially excavated and plugged with earthen backfill. After installation of the new drains, drain discharge and water quality were measured throughout the summer and fall.

Durability of old drains

Excavation of the original drainage pipes revealed that the gravel envelope and clay drainline segments were intact. Bituminous fiber drainlines showed signs of deterioration.

The clay pipes were in excellent condition, but the envelope materials had some silt, and open joint spacings between individual pipes were compressed. This compression reduced the area accessible to soil water, thereby affecting the drainage efficiency of the clay drainlines.

The bituminous fiber drains were slightly flattened in the vertical direction and little effective fiberglass envelope material remained. Substantial amounts of silt within these drainlines (20 to 25 percent of the drain cross-sectional area) indicated failure of the envelope materials. Despite this failure, discharges from the bituminous fiber drains were not significantly different from clay drainline discharges.

Performance

There are several methods of evaluating the performance of a drainage system. For this discussion, we examined flow rates, salt load-flow relationships, and drainage efficiencies of the old drains as they changed in 20 years and as compared with the newly installed plastic drainlines.

In 1966, flow rates in the old drains reached a maximum of 10 to 12 liters (2.6 to 3 gallons) per minute within two days after field flooding, and stabilized at approximately 8 liters (2 gallons) per minute for more than one week. Flow rates of the old drains in 1986-87 behaved similarly in time but at much smaller rates.

A typical example of the drain discharge hydrograph for an old bituminous fiber drain measured in the spring of 1987 showed that flow rates reached a maximum within two days of irrigation (fig. 1). The sustained maximum, however, was only 2 to 3 liters (0.5 to 0.8 gallon) per minute. Flow rates a week after irrigation were less than 1 liter per minute. In contrast, maximum flow rates in the adjacent new drainline were 5 to 6 liters per minute following irrigation, and the other new drainline yielded maximum flow rates of over 10 liters per minute. Although there was some variability in flow rates, it appears that discharge rates in the new drains are several times greater on average than in the old drains. Of continuing research interest is the mechanism by which the drain system responds so quickly to irrigation despite extremely small soil permeabilities.

Salt load-flow relationships are a measure of the capacity of the drainage system to extract salt and reduce the salinity of the root zone. Theoretically, when the salt concentration is constant, there is a direct relationship between salt load and discharge or flow rate; that is, as the flow rate

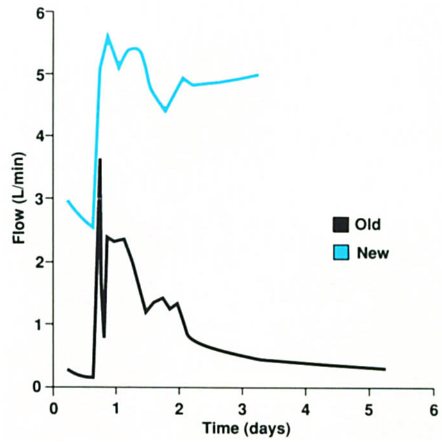


Fig. 1. Typical discharge hydrograph for old bituminous fiber and new plastic drains shows considerably higher flow rates in new drainlines after irrigation.

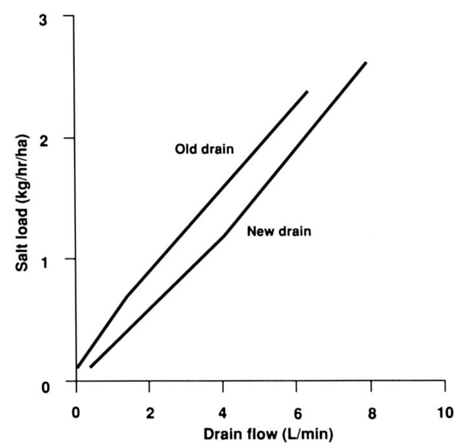


Fig. 2. Same drains show direct relationships between salt load and flow rate.

increases, there is an increase in the salt load, partly due to the increase in flow. When originally installed, the old drainage system showed a seemingly irregular reverse relationship between salt load and flow rate; as flow rate increased, salt load slightly decreased. This measurement may have been a passing effect or related to a lack of soluble gypsum in the soil. Robinson and Luthin, however, concluded that such a relationship was probably due to "a unique combination of hydraulic conductivities along each tile line" such that "areas of high hydraulic conductivity tended to dilute the salinity in the areas of low hydraulic conductivity."

Results of recent measurements of salt load and flow rates of the same old and new drains presented in figure 1 are shown in figure 2. Salt load was calculated from regular measurements of electrical conductivity and less frequent chemical analyses. Roughly direct relationships were obtained for both periods—before and after installation of the new drains. The degree of relationship, however, decreased slightly for the new drains. Data collected from the other drains suggested less disparity than that shown in figure 2. Nevertheless, it appears that there has been little significant change in the salt load-flow relationship between the old and new drainage systems and that this relationship is controlled by evaporation and soil properties (salinity and permeability) rather than by the drains.

Drainage efficiency is a measure of the amount of water draining from the root zone actually collected and discharged by the drains. The efficiency probably depends on several soil-related factors such as cracking and soil moisture conditions. Such an index, in addition to its use as a comparative measure, may be of significant environmental concern with regard to drainage issues of the San Joaquin Valley.

Analysis of Robinson and Luthin's data indicated that average drainage efficiencies ranged from 27 to 33 percent in 1966, and that there was no significant difference in efficiency between the clay, concrete, or bituminous fiber drainlines. Data collected in May 1987 from the old drains indicated a drainage efficiency of 10 percent or less. In contrast, approximately two months later, drainage efficiency of the new drains was nearly 50 percent. Such values suggest that the new plastic drainage system performs slightly better than did the old system when 2.5 years old, and that performance of the old system decreased with time. Future measurements will establish whether performance of the new plastic drainlines declines at the same rate as the old lines did.

Conclusions

Results of this evaluation suggest that bituminous fiber drainlines in a fiberglass envelope degraded over time, but little degradation was found in the clay drainlines. Despite deterioration of the bituminous fiber drainlines, there was little difference in performance between clay and bituminous fiber drainlines.

Drainage system performance declined over the 20-year period as compared with newly installed plastic drainlines and with the old drains when originally installed. Lack of substantial change in load-flow relationships between old and new drains suggests that higher flow rates in the new drains should remove a greater quantity of salts from the root zone. Such removal may improve crop production in this soil.

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