Subsurface drip irrigation (above) controlled annual weeds more effectively than sprinkler (below) or furrow irrigation in plots not treated with herbicides.

Weed control by subsurface drip irrigation

Stephen R. Grattan ❑ Lawrence J. Schwankl ❑ W. Thomas Lanini

Most California growers on irrigated farmland rely on the application of synthetic chemicals to control weeds. Although these chemicals are effective, there are increasing concerns about the long-term effects such materials may have on the quality of soil and water.

Various nonchemical methods have been suggested as alternative means of weed control. These include: (1) mulching, the use of plastic films or residual organic matter layered on the soil surface; (2) cultivation, mechanical removal of weeds before they reproduce; (3) interspecific competition, growth suppression of weeds through crop competition for nutrients, water, and light; and (4) heat, the use of solar energy and clear plastic films over the soil surface to produce heat and reduce weed-seed germination. These methods have effectively reduced weed growth and vigor.

In this article, we discuss water management as an additional ecologically sound and effective method to control annual weeds in summer row crops.

Drip-irrigation tape or tubing buried 10 to 18 inches below the soil surface for several consecutive years is a new irrigation practice that several growers have adopted. Farm managers using this system have noticed that it reduces weed infestation, but this effect of subsurface drip irrigation had not been experimentally tested or quantified. We designed a field experiment at the University of California, Davis, to evaluate the effect of the irrigation method on weed control.

Field experiment

Three irrigation methods were selected: furrow, sprinkler, and subsurface drip. The laterals of the drip system were buried in the plant row, 10 inches below the surface of the bed. Since each method would produce different soil surface wetting patterns, we tested our hypothesis that weed infestation is related, in part, to the soil water content of the top inch of the soil surface. Weed growth was studied in a field of processing tomatoes.

A 2-acre site was divided into 15 randomized plots (each of the three irrigation methods was replicated five times). Each plot contained six (five in the case of subsurface drip), 60-inch-wide beds 150 feet long. Before the irrigation treatments began, annual weed seeds (redroot pigweed and barnyardgrass) were sown evenly on all plots to ensure uniform weed infestation. One row of tomato seeds was sown in the middle of each bed in the first week of May 1987.

Half of each plot was randomly selected and then sprayed with two herbicides—Devrinol (napropamide) at 2 pounds and Tillam (pebulate) at 6 pounds per acre. The other half remained unsprayed. The tomato stand in all plots was established by sprinkler irrigation until plants were nine inches tall. Weeds were manually removed in the plant rows of each plot. On June 24, one day before beginning the various irrigation methods, the entire field was cultivated to remove all weeds.

Each plot received equal amounts of water to replace estimated losses from evapotranspiration (ET). Sprinkler and furrow plots were irrigated weekly; drip irrigation plots were watered daily (every other day before 40 percent canopy cover). No effective rainfall was recorded during the experimental portion of the season—June 25 until September 23. All plots received their last irrigation three weeks before harvest.

A block of weeds and tomato plants, two beds wide and 15 feet long (150 square feet), was harvested from the center of each of the 30 plots on September 23. The tomato fruit was separated into reds, greens, and rots and were weighed. The weeds were dried, weighed, and characterized according to species.

Influence of irrigation method

The total weight and distribution of weeds were related, in part, to the water content (samples taken 24 hours after irrigation) of the surface inch of soil (fig. 1).

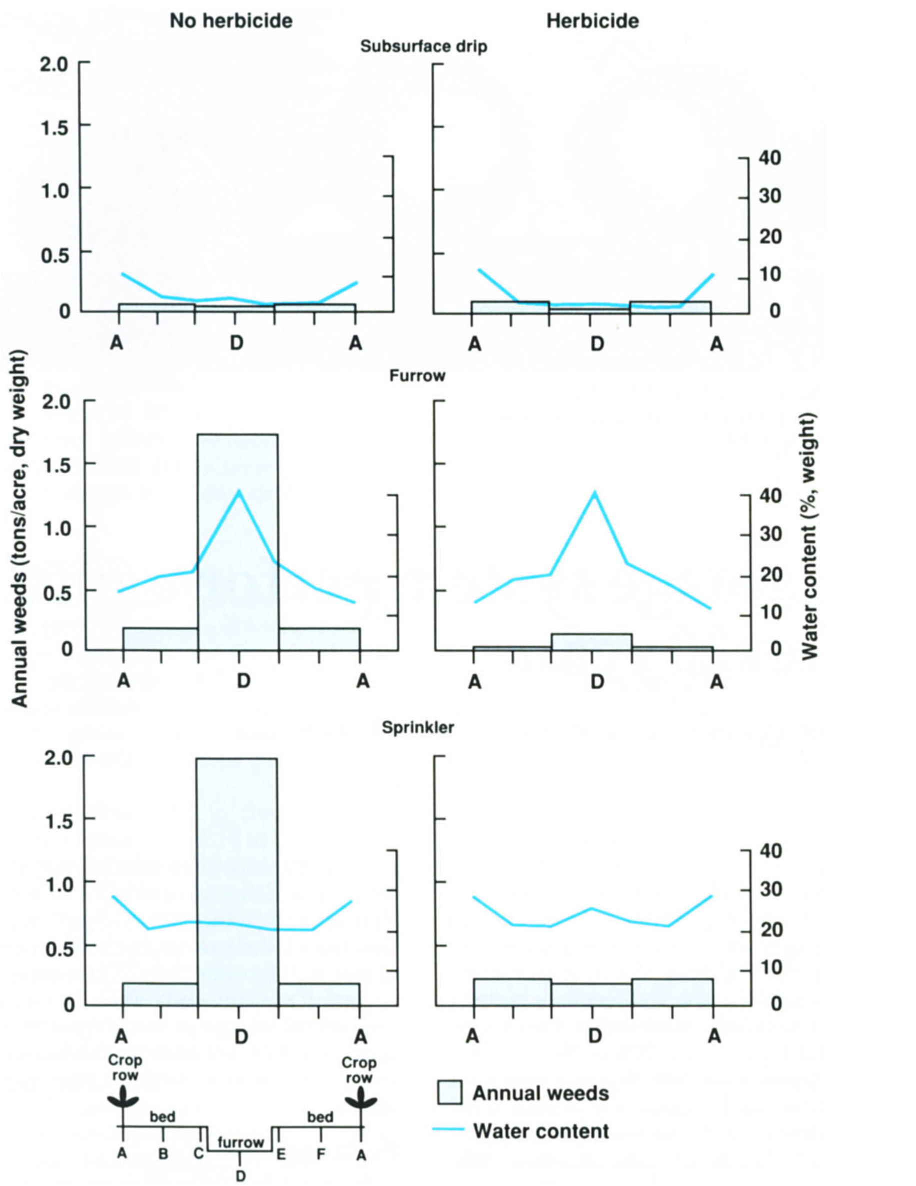

Fig. 1. In furrow and sprinkler irrigation plots not treated with herbicides (graphs at left), weed growth was most vigorous in the furrow area where the water content was highest. Subsurface drip irrigation without herbicides was at least as effective in controlling annual weeds as herbicides were under furrow or sprinkler irrigation (graphs at right).

This zone was monitored because it is generally considered to be the optimal depth for weed germination.

In the case of furrow irrigation, the water content was greater and weed growth was more vigorous in the furrow than in the plant row. Although herbicides largely reduced weed growth, the relationship between soil water and weed growth was the same as in plots with no herbicide. Under sprinklers, the surface soil water content 24 hours after irrigation was uniform within the plot, yet more weeds were found in the furrow than in the bed. This result indicates that weed distribution under furrow and sprinkler irrigation is related not only to the surface soil water content but also to crop density.

The total mass of weeds produced per surface area in fields irrigated by subsurface drip were several orders of magnitude less than were produced under the two other irrigation methods. This is not surprising since, under buried drip irrigation, most of the soil surface remained dry during the season except for a moist strip about 10 inches wide in the plant row. A few annual weeds were able to overcome crop competition and flourish in this strip. Unlike sprinkler- and furrow-irrigated plots, there was no difference in weed growth between herbicide-treated and untreated subsurface drip plots. This indicates that herbicides were not needed to control weeds with this method, at least in the absence of rain.

Growth of field bindweed was not influenced by the irrigation method. This result was not unexpected, since bindweed does not need to propagate from seed but can sprout from storage roots. Establishment of perennial weeds like bindweed is generally not directly related to moisture in the upper portion of the soil profile. Field bindweed is notorious as a difficult-to-control weed with a deep root system. In our study, there was no relationship between field bindweed growth, herbicide treatment, and location across the bed. Field bindweed, however, represented only a small proportion of the total weed biomass (less than 6 percent).

Fruit yield and quality

The yields of red tomato fruit (table 1) were inversely related to the biomass of weeds. The irrigation method did not influence the yield, providing weed density was reduced by herbicides. In the absence of herbicides, the yield was significantly higher with subsurface drip than with the more conventional methods of irrigation. The yield suppression in the furrow and sprinkler plots that were not treated with herbicides was probably caused by weed competition for light, nutrients, and water.

Previous studies have shown that irrigation can affect tomato fruit quality. The fruit in our study appeared to mature more rapidly under subsurface drip than by the other methods. This observation is based on a smaller quantity of green fruit and, to some extent, larger amounts of rotten fruit produced in the subsurface drip plots. We believe this difference is related to a late-season outbreak of mites and powdery mildew which was first noticed in the subsurface drip plots.

The soluble solid content (°Brix) in the tomato fruit was influenced by the irrigation method. Fruit from subsurface drip plots contained significantly lower solids than fruit from either furrow or sprinkler plots. This difference may be due to a reduced cumulative water stress experienced by drip-irrigated plants. There is potential for improving soluble solids in

TABLE 1. Yield of tomatoes under furrow, sprinkler, and subsurface drip irrigation

Irrigation method	Fruit yield*		
	Reds	Greens	Rots
	......	*tons/acre*	.....
Furrow			
No herbicide	35 a	3 a	2 a
Herbicide	45 b	7 b	3 bc
Sprinkler			
No herbicide	35 a	4 a	4 bc
Herbicide	47 b	7 b	3 b
Subsurface drip			
No herbicide	53 b	2 a	4 c
Herbicide	52 b	2 a	4 bc

* Values followed by same letter are not significantly different as determined by LSD test at 5% confidence level.

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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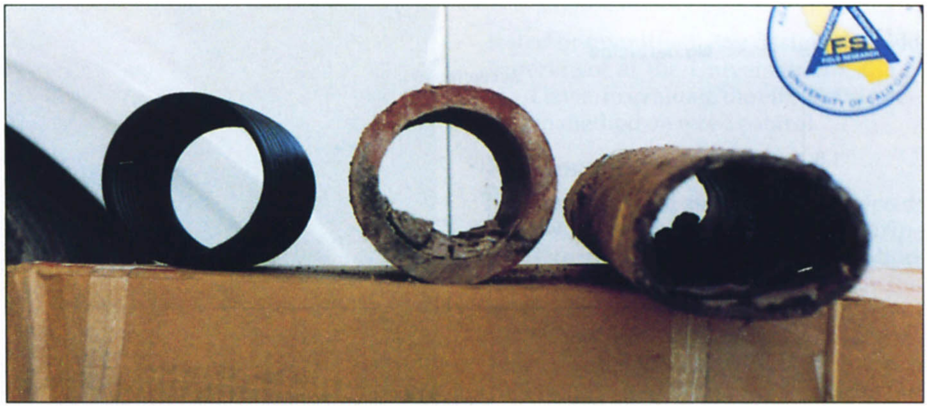

New plastic drain (left) compared with excavated clay and bituminous fiber drains installed in 1964.

Drainage system performance after 20 years

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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