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SOIL and WATER

WINTER 1988 - NO. 73

SUBSURFACE DRIP IRRIGATION: AN ALTERNATIVE METHOD OF WEED CONTROL

Stephen Grattan, Lawrence Schwankl, and W. Thomas Lanini

Alternative practices to control weeds, pests, and diseases that reduce or eliminate the use of pesticides are gaining more attention. These alternative practices are becomming more attractive as concerns related to the long-term effects of petrochemicals on our natural resources continue to grow. This article introduces an alternative means of reducing annual weeds in irrigated cropping systems. Our intension in this study was not to discredit existing alternatives of weed control, such as mulching, cultivation, interspecific competition, and solar heat but to emphasize the importance of water management as an

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Subsurface drip irrigation was able to control annual weeds whereas furrow irrigation was not in plots without herbicides.

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PREEMERGENCE HERBICIDE PERFORMANCE UNDER DRIP AND LOW VOLUME SPRINKLER IRRIGATION

Bill B. Fischer, David A. Goldhamer, Tom Babb and Roger Kjelgren

With the rising costs of water, energy and labor, the use of drip and other low volume types of irrigation (microsprinklers, foggers, misters) can be an attractive alternative to conventional irrigation methods. While the primary advantage of these systems is the potential to improve the uniformity of applied water, a serious, yet common drawback, is the vigorous weed growth that occurs in the wetted surface area. Weed control in frequently wetted soil is often much shorter lived than with conventional low frequency irrigation systems. The mechanisms

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A THIRTY YEAR SOIL MONITORING PROGRAM IN MERCED AND STANISLAUS COUNTIES

Bill Weir, Jewell Meyer and Blaine Hanson

Many of the soils on the westside of Merced and Stanislaus counties are classified as saline-sodic. Yield reductions can be severe, depending on salt concentrations. Efforts made to prevent the buildup of salts in the plant root zone include monitoring both the water used for irrigation and the saline-sodic condition of the soil.

In December 1935, President Roosevelt approved the Central Valley Project, California, a portion of which allowed for of a so-called "Exchange Contract," which provided for a substitutional water supply

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Analysis of these data shows that most of the fluctuations in soil salinity may be due to differences in sampling locations. If this is true, changes in soil salinity with time were relatively insignificant.

Figure 1. EC Values for four Soil Depths. (leaching fraction = >10%)

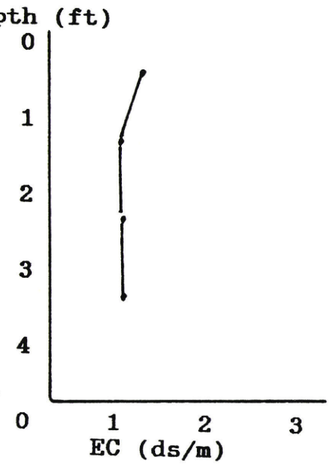


Figure 2. EC Values for four Soil Depths. (leaching fraction = <10%)

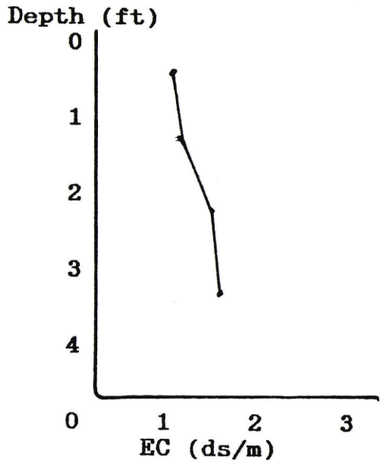
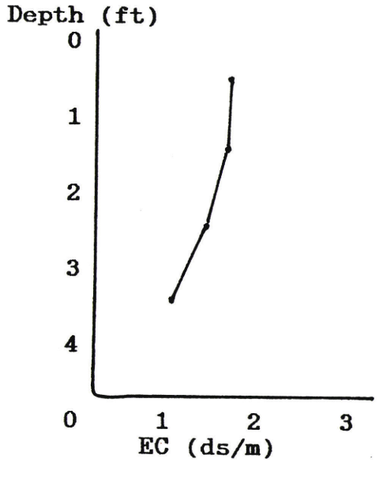


Figure 3. EC Values for four Soil Depths. (leaching fraction = <10-14%)



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SUBSURFACE DRIP IRRIGATION, cont.

additional ecologically sound method of annual weed control.

Drip-irrigation tape or tubing buried 10 to 18 inches below the soil surface for several consecutive years is not a novel irrigation practice, but has been used by several farm managers and scientists. These individuals have noted that this irrigation method reduces weed infestation even though the benefit was not the sole reason for installation of the drip system.

This influence of subsurface drip irrigation on weed control had not yet been experimentally tested or quantified. Therefore, we designed a field experiment on the UC Davis campus to evaluate the effect of the irrigation method on weed control.

Experimental Design

Three irrigation methods were selected (1) furrow irrigation, (2) sprinkler irrigation, and (3) drip irrigation where the laterals 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 soil surface (top one inch). Weed growth was studied in a field of a popular summer annual for this location [processing tomato (Campbells UC 204C)].

A 2-acre site was divided into 15 randomized plots (each of the three irrigation methods were replicated five times). Each plot contained six (five in the case of subsurface drip), 60-inch wide beds that extended 150 feet in length. Before the irrigation treatments were imposed, annual weed seeds (redroot pigweed and barnyardgrass) were dispersed evenly among all plots to assure uniform weed infestation. One row of tomato seeds were sown in the middle of each bed. Half of each plot was randomly selected and then sprayed with two herbicides (Devrinol @ 2 lb/ac and Tillam @ 6 lb/ac). The other half remained unsprayed. The tomato stand in all plots was established by sprinkler irrigation until plants were nine inches in height. Weeds were manually removed in the plant rows of each plot. One day prior to imposing the various irrigation methods, the entire field was cultivated to insure all plots were weed-free before irrigation methods were imposed. Each plot received equal amounts of water in quantities to replace estimated losses from evapotranspiration (ET). Sprinkler and furrow plots were irrigated weekly, while drip irrigation plots were watered daily (drip plots were irrigated every other day before 40 percent canopy cover). No effective rainfall was recorded during the experimental portion of the season which extended from June 25 until September 23, 1987. At the end of the experiment, weeds and tomato fruit were harvested from 150 ft^2 sub-plots. The weeds were dried, weighed, and characterized according to species.

Results

Annual weeds. The distribution of annual weeds across the bed characteristic of each irrigation method is illustrated in Figure 1. The total weight and distribution of weeds was related, in part, to the water content (samples taken 24 hours after the irrigation event) of the surface inch of soil. In the case of furrow irrigation, the water content within the furrow was greater than within the plant row and consequently, weed growth was more vigorous in the furrow. Although herbicides largely reduced weed growth, the same relationship between soil water and weed growth was observed in the sprayed treatment. Under sprinkler irrigation, the soil

water content did not change over the soil surface, yet more weeds were found in the furrow than within the bed. This indicates that the weed distribution under furrow and sprinkler irrigation is related not only to the soil water content in the surface soil, but the crop density as well.

The total weed biomass, defined here as the mass of weeds per surface area, in fields irrigated by subsurface drip were orders of magnitude less than that produced under the two other irrigation methods. This is not surprising since most of the soil surface remained dry during the season. There was a moist strip of soil about 10 inches wide within the plant row. In this strip, a few annual weeds were able to overcome crop competition and flourish. Unlike sprinkler and furrrow irrigation methods, 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 under arid conditions.

Perennial weeds. Growth of the field bindweed was not influenced by the irrigation method. These plants do not need to propogate from seed but can sprout from viable storage roots. Therefore, establishment of perennial weeds is not directly related to soil moisture conditions in the upper portion of the profile. Field bindweed is notorious as a difficult-to-control weed. In our study, there was no relationship between field bindweed growth, herbicide treatment and position across the bed. Field bindweed, however, represented only a small proportion of the total weed biomass (<6%).

Fruit Yield. The yields of red tomato fruit (Table 1) were directly related to the biomass of weeds (r = -.71***). 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 wth subsurface drip than with the more conventional methods of irrigation. The yield suppression in the furrow and sprinkler plots that were not treated with herbicide was most likely caused by weed competition for light, nutrients, and water.

Table 1. Yield (tons/ac) of tomatoes under furrow, sprinkler, and subsurface drip irrigation.

Irrigation Method	Fruit Yield (tons/ac)*		
	Reds	Greens	Rots
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.

Fruit quality. Previous studies have shown that irrigation can effect tomato fruit quality. The fruit in our study appeared to mature more rapidly under subsurface drip than by the other methods. This conclusion 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 that this difference is related to a late-season outbreak of mites and powdery mildew which was first noted in the subsurface drip plots.

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THIRTY YEAR SOIL MONITORING PROGRAM, cont.

for waters of the San Joaquin River. The Westside was affected by the "Exchange Contract," since its new irrigation water supply would be higher in salt content than the original supply from the San Joaquin River. Sacramento River water, carried by the Delta-Mendota Canal, has 500 to 600 ppm TDS by the time it arrives in the Central California Irrigation District canals. Since the San Joaquin River water was lower in salt concentration, there was some question as to whether salinity of the agricultural soils would increase over a period of time with the use of the "Exchange Contract" water.

In the early 1950's, University of California Soils Specialists Warren Schoonover and W. P. Kelly set up a soil sampling program to monitor any changes in salt content in eight different soil types in western Merced and Stanislaus Counties. This paper reports on all eight soil sampling sites and covers the time period extending from initiation of the project to its termination in 1985.

Materials and Methods

Six locations in Merced County and two in Stanislaus County were selected for a long-term salinity survey. Locations represent the major soil series used for agriculture in the area; they all were clay or clay loam soils with no hardpan or impermeable layers in the root zone. Beginning in 1955, soil samples were taken at each site in March and October, each year. Central California Irrigation District provided surveyors to locate the exact sampling site and Cooperative Extension performed the sampling and laboratory analyses. A distance of 100 feet was measured from the surveyor's flag and soil samples taken at 10-foot intervals using a king tube. The ten 0 to 1 foot samples were mixed to form a composite sample. Likewise, the 1 to 2 foot samples, 2 to 3 foot samples and 3 to 4 foot samples were composited to form a total of four soil samples for analyses. Samples from each location were taken to the Cooperative Extension laboratory for electrical conductivity determinations.

Results and Discussion

ECe determinations on soil from the eight sites were placed in three broad categories based upon the leaching which occurred. Soil salinity at four of the sites was very uniform with depth. Figure 1 shows the typical ECe values less than 1.0 dS/m for the sites with a leaching fraction of approximately 20 percent.

The second category contained three sites in which soil salinity increased with depth, indicating that a leaching fraction existed, but was not sufficient to maintain uniform salinity in the profile. ECe determinations increased with depth from about 1.0 dS/m at the 1-foot depth to about 1.5 at 3 and 4 feet (Figure 2). Leaching fractions among this group were 10 percent.

A third category, representing only one site, had a decrease in soil salinity with depth. Salinity was about 1.2 dS/m at the surface and decreased to 0.9 at the 4.0 foot level (Figure 3).

Data collected each year were plotted on a master graph to help detect changes occurring in the salinity content of the soil. No trend in soil salinity appeared to exist with time. Although the data shows fluctuations at some sites, the reasons for these cannot be adequately explained, although an increase in salinity during 1975-78 might be associated with the drought during those years.

Table 2. The performance of herbicides under drip and low volume sprinklers in a deciduous orchard.

1983

		% Weed control in wetted area[1/]			
		4/6/83		10/12/83	
Herbicides	kg ai/ha	Drip	Sprinkler	Drip	Sprinkler
Napropamide+Simazine	4.5+1.1	96	98	22	88
Oryzalin + Simazine	4.5+1.1	100	100	42	85
Napropamide+Oxyfluorfen	4.5+2.2	97	94	65	93
Oryzalin	4.5	97	97	37	84
Napropamide+Simazine +Oxyfluorfen	2.2+1.1+2.2	100	96	65	93
Oryzalin+Simazine +Oxyfluorfen	2.2+1.1+2.2	99	90	58	93
Oxyfluorfen	3.3	98	95	15	96
Untreated	---	39	28	22	28

1984

		% Weed control in wetted area[1/]					
		5/19/84		8/22/84		10/20/84	
Herbicides	kg ai/ha	Drip	Spklr	Drip	Spklr	Drip	Spklr
Napropamide+Simazine	4.5+1.1	57	93	85	90	66	81
Oryzalin + Simazine	4.5+1.1	97	100	78	99	73	86
Napropamide+Oxyfluorfen	4.5+2.2	93	97	87	97	78	90
Oryzalin+Oxyfluorfen	4.5+2.2	96	93	80	99	76	93
Napropamide+Simazine +Oxyfluorfen	2.2+1.1+2.2	97	99	90	99	85	93
Oryzalin+Simazine +Oxyfluorfen	2.2+1.1+2.2	100	98	78	99	90	96
Oxyfluorfen	3.3	90	98	88	98	75	83
Oxyfluorfen+Simazine	2.2+1.1	99	99	87	99	76	90
Untreated	---	0	30	87	83	26	35

[1/] 0 rating is no control; 100 is total control.

Discussion

Concerns related to grower adoption. There are several concerns with regards to adoption of subsurface drip irrigation for the control of weeds. First of all, there is uneasiness among growers due to their inability to visually determine if their system is functioning properly. Therefore, the system should be designed to access the lines to monitor pressure. Secondly, the initial costs for materials (line, filtration units, fittings, etc.) and installation are high. However, individuals that use this system claim that costs are offset in subsequent years by reduced traffic demands in the field as well as labor savings. It is anticipated that the buried drip tubing could remain buried for several years. Third, the system requires careful management to mitigate problems due to infiltration, orifice clogging, leaks, etc. Consequently, the grower or irrigation manager must be alert to avoid these problems and must be innovative in learning an entirely new cropping system, not just a new irrigation system. 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 accomodate a fixed spacing of buried drip tubes. This may require changes in cultural practices.

Potential advantages. Despite the concerns and limitations indicated above, there are additional benefits with subsurface drip irrigation. The practical efficiency of water application in a well managed system can be quite high (80 to 90 percent). Of equal importance, in areas where water inifiltration is poor in the mid to late season, this system can avoid that problem.

The buried drip system allows the grower to deliver nutrients close to the root by injecting liquid fertilizers into this system. The quantities and proportion of various nutrients can be delivered in accordance with plant demand. This has the potential to increase the efficiency of fertilizer use (defined here as the percent of fertilizer applied that is consumed by the crop). Improved fertilizer efficiency has both environmental and economic benefits. Furthermore, since the surface soil is never saturated with water, the incidence of root disease may be reduced. This hypothesis remains to be tested.

Summary

Non-chemical methods of weed control will gain more interest as we search for cropping systems that are less dependent upon herbicides. In Mediterranean climates, such as California, 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.

Although the subsurface drip system offers numerous potentials related to the plant-soil-water environment, we do not anticipate or encourage rapid adoption by all growers. In certain locations, growers are unable to convert to drip irrigation due to inflexability in water delivery schedules. Adoption should take place on a small scale most likely by innovative growers that are careful managers due to the need to learn new methods of irrigation, fertilization, cultivation, and pest control. At present, this irrigation method for weed control would be most attractive to small growers that produce crops without pesticides or by transitional growers moving from strong to reduced chemical dependence.

Figure 1. Influence of the irrigation method on the distribution of annual weeds and soil water content (upper 1 inch) across the bed.

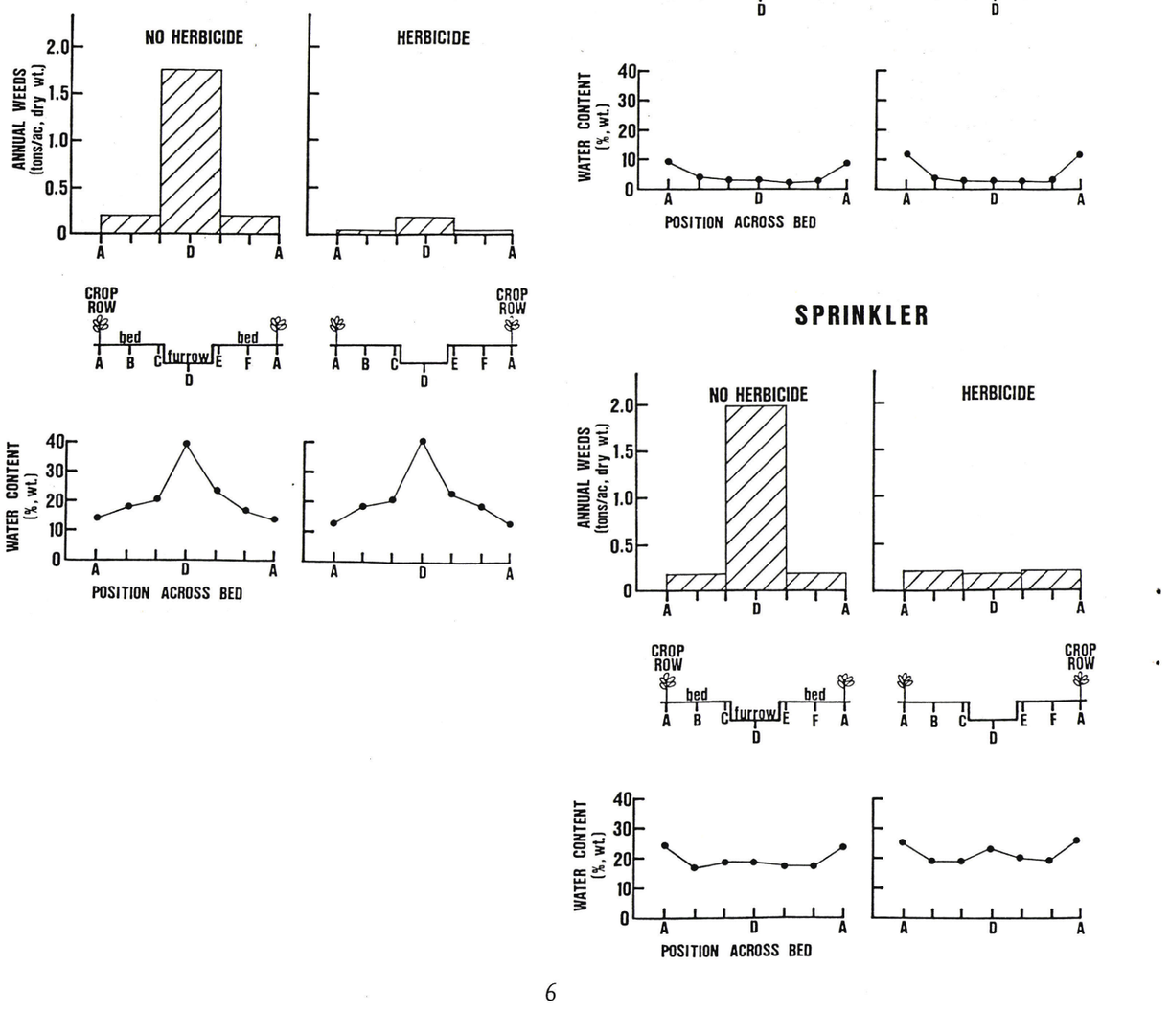

Table 1. Evaluation of the performance of herbicides under different methods of irrigation in a vineyard.

Herbicide[1]	Kg ai/ha	% Weed control in wetted area[2] Basin flood	Drip emitter	Mist emitter
Diuron+Simazine (Karmex+Princep)	1.7+1.7	98	35	55
Oryzalin+Simazine (Surflan+Princep)	4.5+1.1	100	25	50
Napropamide+Simazine (Devrinol+Princep)	4.5+1.1	85	25	40
Oryzalin+Simazine+ Oxyfluorfen (Surflan+Princep+Goal)	2.2+1.1+2.2	100	35	60
Napropamide+Simazine+ Oxyfluorfen (Devrinol+Princep+Goal)	2.2+1.1+2.2	98	50	65
Napropamide+Simazine (Devrinol+Princep)	4.5+2.2	90	35	40
Oryzalin+Simazine (Surflan+Princep)	4.5+2.2	85	35	50
Oxyfluorfen+Simazine (Goal+Princep)	2.2+1.1	80	0	30

[1] Glyphosate was added to all treatments at 2.2 kg ai/ha.

[2] Herbicides applied on 3/5/82 and 2/18/83. Evaluated on 11/19/84. 0 rating is no control; 100 is total control.

responsible for poor preemergence herbicide performance are tied to the water management strategies associated with drip and low volume irrigation; strategies that are fundamentally different from conventional irrigation practices.

Irrigation scheduling with conventional methods in most soils involves water application every two or three weeks during much of the season. However, with drip and low volume sprayers, water is applied frequently; usually on a daily basis in drip and two to three times per week with low volume sprinklers. The degradation of preemergence herbicides appears to be, in large part, a function of the magnitude and duration of high soil water contents. Thus, high frequency irrigation can result in poor performance of these chemicals.

In soil that is frequently wetted, summer annual grasses and broadleaf weeds, especially Echinochloa crus-galli, Digitaria sanguinalis, Amaranthus albus, Portulaca oleracea, and Gnaphalium purpureum grow vigorously and are difficult to control. In many orchards it has been reported that weeds, such as Leptochloa sp. and Ammannia coccinea, that commonly occur in rice fields, became prevalent. Soil persistent herbicides applied preemergence, such as napropamide and oryzalin, apparently do not provide adequate long-lasting control, requiring the use of contact or systemic herbicides such as paraquat, dinoseb and glyphosate. For example, some orchardists have found it necessary to treat the area around drip emitters four to eight times a year to control weeds. This is a costly practice and guidelines are needed for growers to eliminate or minimize this expense.

To investigate the dynamics of weed growth and control under different irrigation methods, field experiments were conducted at the University of California Kearney Agricultural Center in Fresno County, California.

Methods

Evaluations were conducted in a vineyard and deciduous orchard. The vineyard study utilized 15 rows of mature Thompson seedless grapes divided into three, five-row plots. One plot was equipped with low volume sprinklers suspended from raised, above-ground laterals, with sprinklers installed midway between the vines. Both 360 degree and 40 degree spray patterns, that direct the water along the vine rows, were evaluated. Two drip emitters per vine, spaced 0.79 m on either side of the trunk, were installed on another plot, with a separate automatic controller to allow for different durations of water application than the low volume sprinklers. Volumetric discharge rates were 4.0 and 20 liters/hr through the emitters and sprinklers, respectively. Irrigations took place daily in the drip; twice a week in the low volume plots. The duration of irrigation was based on long term historical crop water use. The third plot was border strip irrigated. A strip of raised soil (berm) approximately 1 m wide under the vines confined the water to a 2.4 m wide basin between the vine rows. Again, a water budget procedure bases on historical crop ET was used to schedule irrigations in the border strip plot, which averaged once every 20 days.

The herbicides were applied in mid February with a commercial type sprayer. Application was made to a 1.5 m wide area centered on the vine row. The native vegetation between the rows was mowed periodically during the season. Eight herbicide regimes, plus a nontreated control, were tested under each irrigation method (see Table 1).

In the deciduous tree study, drip and low volume sprinklers were evaluated on young barefoot Flavorcrest peach, Nubiana plum, Nonpareil and Mission almonds planted in early 1982. Two varieties of almonds were used because they differ significantly in their susceptibility to certain herbicides. For each irrigation method, 27 plots, each containing four trees, one of each variety, spaced 5.2 m apart were established in a randomized block design. Herbicide applications were limited to a 1.2 m strip on each side of the tree rows. Therefore, the herbicide treated area in each plot was 2.4 by 20.7 m. Eight herbicide regimes, plus a nontreated control, were replicated three times (see Table 2). The herbicides were applied with an experimental sprayer in early March of 1982 and the treatments were repeated in succeeding years in mid January.

Weed control evaluations in the vineyard and orchard were made periodically each year and rated on a scale from 0 (no control) to 100 (total control). Following each evaluation, weeds present in all plots were sprayed with glyphosate or sulphosate. Hence, on each evaluation date only newly emerged weeds were rated. This allowed assessment of the effectiveness of herbicides on numerous weed species and their persistence under the different methods of water application.

The net amount of applied water available for crop use was the same under each method of irrigation. Applied water was based on the long term historical daily evapotranspiration (ET) estimates and published crop coefficient values for grapes and deciduous trees. Adjustment for immature tree canopy size was based on the shaded area of the orchard floor measured midday during the summer. Application efficiencies were estimated at 70 percent for the locally irrigated trees in 1983, and 90 percent in 1984. For the vineyard, application efficiency estimates were 75 and 90 percent for the border strip and locally irrigated vines, respectively.

Results and Discussion

The evaluations of weed control under both cropping situations reflected the susceptibility of the weeds to the applied herbicides and their persistence under the different irrigation methods. In both the deciduous tree and vineyard studies, all herbicide treatments provided very effective weed control through mid May regardless of the method of irrigation. However, in the deciduous orchard, later evaluation indicated that all herbicide treatments under the low volume sprinklers provided better weed control when compared with their performance under drip. As the season progressed, the differences in the effectiveness of weed control became greater, as illustrated by the October evaluation in 1983 shown in Table 1.

In the vineyard study, the most effective and longest residual weed control was obtained with border strip irrigation, where no irrigation water was applied over the herbicide treated area. As opposed to the orchard study, no appreciable difference in weed control was observed between the drip and low volume sprinklers throughout the season. This was attributed to the disruption of the sprinkler's spray pattern by low hanging canes of the vines. Interception of the applied water by the foliage and the subsequent deposition of this water directly beneath the point of interception resulted in a wetted surface area similar to that associated with drip emitters. The duration of soil wetness beneath the vines was enhanced by the architecture of vine canopies, which limited surface evaporation and promoted high humidity. It should be pointed out that mechanical cane

cutting (removal of the canes within approximately 0.5 m of the soil surface) is a common practice in the production of certain grape varieties. This facilitates an uninterrupted spray pattern, and would presumably improve herbicide performance with low volume sprinklers.

In the orchard the most weed control under low volume sprinklers throughout the 1983 season was recorded in areas treated with oxyfluorfen (see Table 2). On the other hand, oxyfluorfen under drip irrigation resulted in poor seasonal herbicide performance. Generally, the more effective weed control with the drip irrigation was obtained where oxyfluorfen was applied in combination with oryzalin. Under the low volume sprinklers, the same herbicide combinations resulted in substantially better weed control.

In both studies, shifts in weed populations were observed in 1984. Weed species that are tolerant or marginally susceptible to certain herbicides or combinations of herbicides became dominant. For example, in the oxyfluorfen treated plots, Gnaphalium sp., Conyza canadensis, and Conyza bonariansis were the prevalent weeds. In both the drip and low volume sprinkler plots, this resulted in superior weed control in areas treated with combinations of three herbicides; oryzalin, simazine, and oxyfluorfen or napropamide, simazine plus oxyfluorfen (see Table 2).

Conclusions

These studies demonstrated that more effective and longer residual weed control can be obtained with preemergence herbicides under low volume sprinklers than with drip emitters. This is presumably due to the more rapid microbiological and chemical (hydrolysis) degradation of herbicides in the continually wetted soil associated with high frequency drip irrigation.

Thus, it appears that the use of low volume sprinklers, while having most of the advantages of drip emitters, offer the potential of better preemergence herbicide performance due to less frequent and concentrated water applications. However, since the management of unwanted vegetation continues to be troublesome and expensive in orchards and vineyards under localized irrigation, research is planned to evaluate the effectiveness and selectivity of certain herbicides introduced in the irrigation system through drip emitters and low volume sprinklers.