

Deep cultivation and gypsum as potential solutions to slow water penetration

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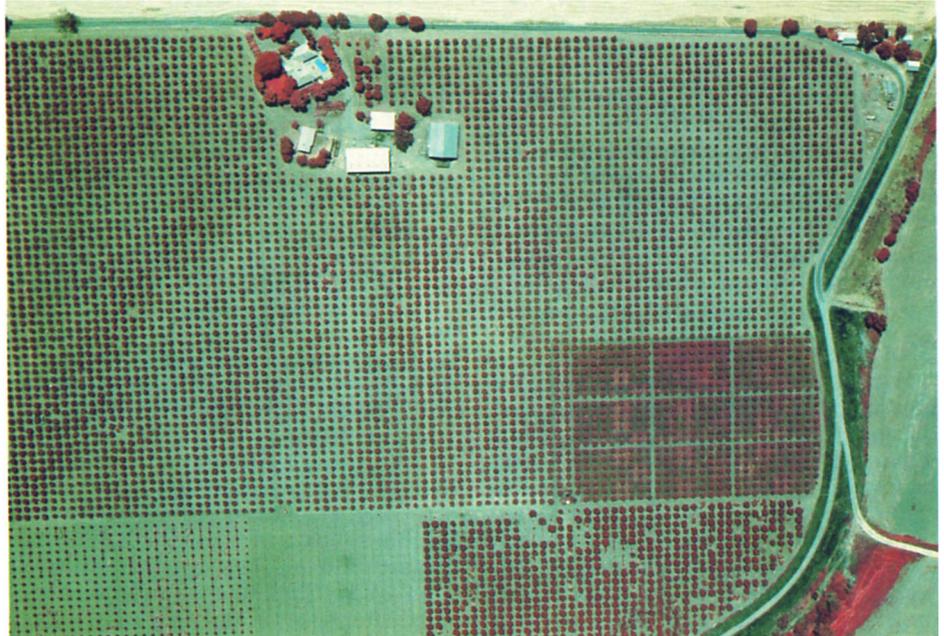
Over 2.5 million acres of California farmland have some form of water penetration problem during the irrigation season, according to a recent survey by Cooperative Extension farm advisors. In some cases, simply increasing the length or frequency of irrigation may alleviate the problem and provide sufficient water to the crop. In other cases, the problem is more serious: crop yields are reduced and health and vigor of trees and vines are adversely affected, even with careful water management.

In the absence of perched water tables, water penetration is controlled by the size and number of soil voids. Large surface openings, such as cracks in clay soils, worm holes, and old root channels, rapidly convey water from the surface into the soil. Large pores between aggregates and individual sand grains also allow water to pass quickly from the surface to the subsoil.

Final infiltration rates are naturally slow in soils with clay surface textures or with hardpans or claypans in the subsoil. These conditions are generally managed by adjusting the crop or irrigation method in the case of clay soils, or by ripping in the case of hardpan or claypan soils. Water usually infiltrates rapidly into sandy and medium-textured soils, but mechanical compaction or chemical dispersion can result in slow water penetration. Solving water penetration problems in these soils may be more difficult than in soils with clay surfaces or subsoil pans.

Compaction results from tillage, spraying, planting, and harvesting with heavy machinery. The weight and vibrations of the machinery from repeated farming operations cause aggregates to break apart and particles to reorient, so that the pores become smaller within and below the cultivation zone. In addition, the number of connections between pores may be reduced, further slowing the flow of water.

Irrigation can cause surface soil aggregates to disperse if the water is high in sodium and low in other salts, or if the water is of good quality (low salt) and the soil contains small amounts of exchangeable sodium. This dispersion can lead to surface crusting and sealing



Infiltration study was conducted in prune orchard shown in this false-color infrared photo. Orchard is typical of those near Feather River in northern California. (William Wildman photo)

when individual soil particles are washed into and block pores or are oriented in horizontal surface layers. Sodium in the soil or low-salt waters are not necessary for crust formation, but they do aggravate the problem.

In June 1983, we began an experiment to identify the cause of slow infiltration in a prune orchard north of Marysville in Yuba County and to find out if deep tillage, or gypsum, or both, would reduce the problem.

Orchard experiment

We established a set of randomized plots in the orchard in May 1983. Each plot included one traffic row, was bordered by four trees, and was separated from other plots by two rows of trees. Trees were in a 20-foot (north-south) by 22-foot (east-west) pattern, and plots extended past the trees 10 feet north and south and 12 feet east and west, for a total plot area of about 1,760 square feet. Treatments, each replicated three times, were: deep tillage; phosphogypsum; a combination of deep tillage and phosphogypsum; and a no-treatment control.

Deep tillage was simulated by two 2-

foot-wide, 5-foot-deep, 20-foot-long backhoe trenches in the center of the tree rows, excavated in a cross pattern and refilled. Phosphogypsum, a fine-grained byproduct of phosphorus fertilizer production containing about 1 percent phosphorus, was applied by hand after trenching, at the rate of 2 tons per acre to the entire plot and disked into the surface soil.

We made three sets of infiltration measurements (trials 1, 2, and 3) during the growing season: the first shortly after plots were installed and before any irrigation; the second after the first (and only) irrigation; and the third after harvest. The cumulative depth of water infiltration from one double-ring infiltrometer in each plot was measured at several intervals during a 24-hour period, and the final infiltration rate was calculated. Between measurements, the grower continued with normal tillage, spraying, and harvest practices.

Before establishing the research plots, we had collected soil samples from an area near the plots in the orchard and determined aggregate stability by wetting aggregates of less than 2 mm under vacuum and then dunking them in wa-

ter. The percentage by weight of water-stable aggregates was then calculated from the dry weight of original samples and the dry weight of aggregates remaining after dunking. Soil particle size distribution, organic carbon content, and exchangeable sodium percentage were determined by standard methods.

Results

In trial 1 (first set of measurements), surface soil water content was higher in the deep-tillage (trench) plots because of the mixing of moist subsoil during excavation. This difference in moisture content did not appear to influence the results of this trial.

Cumulative 24-hour infiltration volume was significantly greater for the trench and trench-plus-gypsum treatments than for the gypsum or control treatments. There was no significant difference between the control and gypsum treatment or between the trench and trench-plus-gypsum treatment.

In this trial, the incorporated gypsum treatment had no beneficial effect on cumulative infiltration, nor did it affect final infiltration rate.

The very large increase in cumulative infiltration and final infiltration rate, which we observed in the two trenching treatments as compared with the gypsum and control treatments, indicated that a dense subsoil was one cause of slow water intake at this site. This conclusion was supported by bulk density measurements on clods from the soil surface and subsoil (1½ to 3 feet), which averaged 1.6 and 1.7 grams per cubic centimeter, respectively, before trenching. High bulk densities are related to decreased porosity, and trenching reduced the average density, increasing the infiltration rate.

A successful treatment, however, should last for at least an entire season. Subsequent measurements indicated that the beneficial effects of trenching alone did not persist past the first irrigation.

In the second set of infiltration measurements (trial 2), after irrigation, surface soil water content was higher than in trial 1, and treatments showed no significant differences in water content at 6 inches (table 1). Samples from a 12-inch depth in the trenched treatments had higher moisture contents than in the control or gypsum treatments, possibly as a result of increased infiltration during the irrigation.

Treatments did not differ significantly in either the cumulative 24-hour or final infiltration rates (table 2). However, the cumulative and final rates for the control and gypsum treatments were higher (but not significantly different) than in trial 1. This increase may have

TABLE 1. Soil moisture at 6, 12 and 18 inches in trials 2 and 3 for the four sets of plots on Wyman soil

Treatment	Soil moisture*					
	6 in. Trial #		12 in. Trial #		18 in. Trial #	
	2	3	2	3	2	3
	----- % -----					
Control	11.6 a	4.5 a	10.2 a	6.1 a	NM	5.5 a
Gypsum	11.8 a	5.4 a	10.5 a	6.0 a	NM	4.4 a
Trench	11.2 a	8.1 b	13.2 b	9.0 ab	NM	8.7 b
Gypsum + trench	11.5 a	7.2 b	14.8 b	9.8 b	NM	9.5 b

Note: Trial #1 moisture data not evaluated. Trial #2 was in July 1983 after an irrigation. Trial #3 was in September 1983 after harvest.

* The same letters following numbers indicate no statistically significant difference at 0.06 level using F tests and simple comparison of means.

TABLE 2. Cumulative 24-hour infiltration and final 24-hour infiltration rate measured by double ring infiltrometer on the Wyman soil

Treatment	Cumulative 24-hr infiltration*			Final 24-hr infiltration rate*		
	Trial #			Trial #		
	1	2	3	1	2	3
	----- cm -----					
Control	5.88 a	9.03 a	11.86 a	0.11 a	0.16 a	0.21 a
Gypsum	6.96 a	8.66 a	22.15 b	0.06 a	0.17 a	0.64 b
Trench	27.40 b	9.57 a	21.00 b	0.55 b	0.14 a	0.26 ab
Gypsum + trench	30.40 b	9.10 a	21.60 b	0.43 b	0.17 a	0.55 b

Note: Trial #1 was in May 1983 before any irrigation.

*The same letters following numbers indicate no statistically significant difference at 0.05 level using F tests and simple comparison of means.

TABLE 3. Selected chemical and physical properties of the Wyman Soil, surface horizon, 0-30 cm (0 to 1 foot)

Aggregate stability	Organic carbon	E.S.P.*	2-1mm	Sand fractions					Silt	Clay
				1-5	.5-.25	.25-.1	.1-.05			
----- % -----										
63	0.54	4.8	12.5	21.9	11.6	13.8	9.9	21.6	8.7	

*Exchangeable sodium percentage.

resulted from interaction of soil condition and measurement method. The rings of the infiltrometer are pounded into the ground before water is added. During the growing season, the compacted subsoil layer became more difficult to penetrate: the rings penetrated the pan in the first trial but were barely able to enter it in the second and third trials. Thus, the higher infiltration rates for the control and gypsum treatments reflect increased lateral flow of water between the infiltrometer rings and the pan rather than vertical flow into the soil.

Our results show that neither the gypsum nor trenching treatments improved water intake after the first irrigation. Either the surface crust reformed, the soil density increased, or water penetration in the trenched plots was inhibited by a residual high water content following irrigation. Decreased 24-hour and final infiltration rates in trial 2 indicate that both the surface crust and increased subsoil density were reestablished by the time we made the second set of measurements.

After harvest, we ran a final set of infiltration measurements (trial 3). The original trench plots were reexcavated to 18 inches and an additional 5 tons per acre of phosphogypsum was spread on the surface of these and the original gypsum-only plots. Control plots remained untreated.

Cumulative 24-hour infiltration depth in the treated plots was nearly twice as great as in control plots. Also, when compared with trial 2, cumulative infiltration more than doubled in the treated plots but was only slightly greater in the control plots. As in trial 2, lateral movement of water between the compacted pan and the infiltrometer rings accounted for a larger proportion of the infiltrated water in the control and gypsum plots than in the trenched and trench-plus-gypsum plots.

The final infiltration rate for trial 3 followed a pattern similar to the cumulative infiltration, except that the final rate in trenched plots was less than in gypsum and trench-plus-gypsum plots. However, this difference was not statistically significant because of the vari-

ability in infiltration rate measurements.

The results of trial 3 clearly demonstrate the benefits of surface-applied gypsum in promoting cumulative infiltration and in maintaining high infiltration rates. The cumulative 24-hour infiltration resulting from surface-applied phosphogypsum was more than three times the amount in trial 1, where the phosphogypsum was cultivated into the soil. The final 24-hour rate for the surface application was nearly 10 times the rate in trial 1 (table 2). It appears that cultivation in trial 1 either dispersed the gypsum throughout the top 4 to 6 inches of soil, thereby diluting its effectiveness, or removed it entirely from the soil surface.

The effect of trenching in trial 3 was less apparent because of the lateral movement of water in the untrenched plots.

Management implications

The Wyman soil in this orchard has poor aggregate stability, as measured by the percentage of stable aggregates remaining after dunking in water (table 3). The low stability is a reflection of low organic carbon, high sand, and low clay contents. In addition, the low but significant exchangeable sodium percentage, when combined with the low salt content (saturation extract electrical conductivity = 0.55 decisiemen per meter) is conducive to clay dispersion and aggregate breakdown.

This study shows that phosphogypsum at 5 tons per acre improves water penetration. Phosphogypsum adds salts to the soil solution as irrigation water enters the soil, thereby promoting aggregate stability. However, it is effective only if it remains on the soil surface before irrigation. At this time, we do not know how long the treatment will remain effective, but we do know that gypsum is ineffective when disked into the soil.

Traffic compacts the subsoil and crushes the few surface aggregates. Deep tillage is required to break up established compaction pans and significantly improves water penetration, but this treatment is short-lived if there is continual traffic over the soil. Reduced traffic after deep tillage may be beneficial.

We have not determined whether the phosphogypsum application or deep tillage are economical, or if the improvement in water infiltration results in better tree health, vigor, yield, or crop quality.

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Managing spider mites in almonds with pesticide-resistant predators

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During the past three years, we have investigated the use of pesticide-resistant strains of a spider mite predator released into almond orchards as components of an integrated management program. This predatory mite, *Metaseiulus occidentalis* (Nesbitt), provides effective biological control of the Pacific and two-spotted spider mites, *Tetranychus pacificus* McGregor and *T. urticae* Koch, respectively, as well as the European red mite, *Panonychus ulmi* (Koch).

Some insecticides used to control the navel orangeworm, *Amyelois transitella*

(Walker) and the peach twig borer, *Anarsia lineatella* Zell., however, can disrupt this biological control. Sevin (carbaryl) and Pounce or Ambush (permethrin) can induce serious spider mite outbreaks, in part because they kill native strains of *M. occidentalis* and other predators of spider mites.

Conventional rates of pesticides that are specific for spider mites, such as Omite (propargite), Plictran (cyhexatin), or Vendex (hexakis), can also disrupt biological control by the predatory mite. If most of the spider mites are killed, these obligate predators will starve or disperse out of the orchard because of the lack of food.

We genetically selected *M. occidentalis* in the laboratory for resistance to the insecticides Sevin and Pounce/Ambush, then developed strains resistant to several pesticides through laboratory crosses and selection. One strain is resistant to Sevin and organophosphorus (OP) insecticides such as Guthion (azaphosmethyl), Diazinon, and Imidan (phosmet), and another is resistant to OP, Sevin, and sulfure pesticides. These resistant strains were evaluated in the laboratory, greenhouse, and small field plots for their ability to become established, control spider mites, overwinter, and survive pesticide applications. The Sevin-OP and Sevin-OP-sulfur resistant strains performed well in these small trials, so large scale releases were made.

During the 1981, 1982, and 1983 field seasons, we inoculated commercial almond orchards with the Sevin-OP- and Sevin-OP-sulfur-resistant predators. To do so, we reared large numbers of predators, using a greenhouse of a soybean field plot method (see *California Agriculture*, January-February 1982). Low rates of the selective acaricides Omite or Plictran were evaluated for possible use in adjusting the spider mite:predator ratio, thereby helping the predator



Almonds at hull split, near harvest time. Pesticide-resistant predators help control spider mites in California almond orchards.