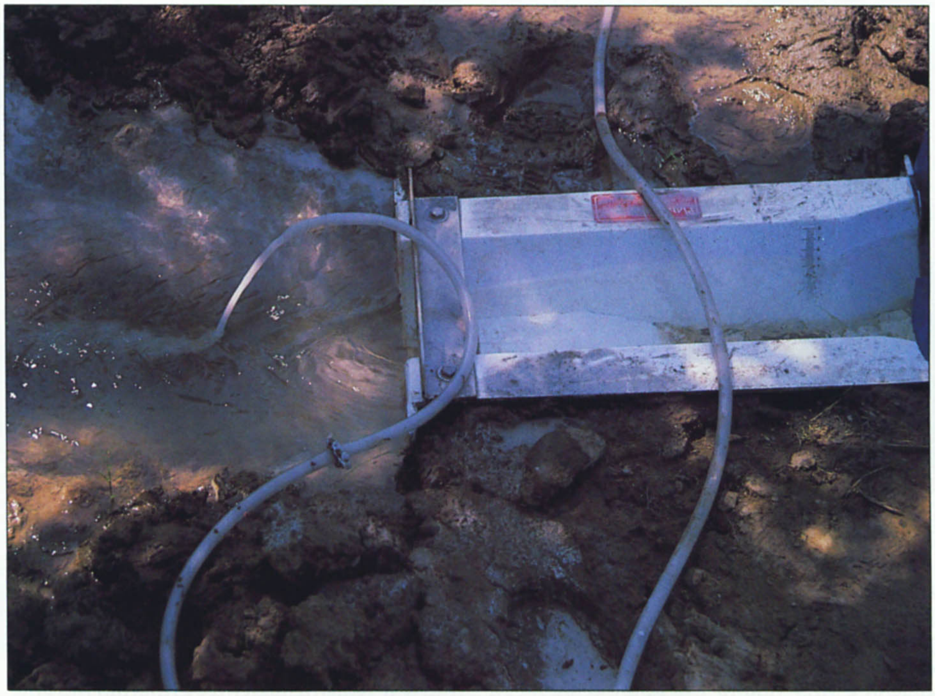

Slurry from the gypsum-dissolving machine is continuously added at the upper end of an almond orchard irrigation check during a14-hour irrigation. Trapezoidal flumes were used to measure both applied and runoff water in the experiment.

Calcium amendments for water penetration in flooding systems

William E. Wildman ❑ William H. Krueger ❑ Richard E. Pelton

Dissolved gypsum and calcium nitrate each increased infiltration rates over the control for each of the 15 irrigations to which they were added. An equivalent amount of gypsum spread on the surface at the beginning of the experiment had the same beneficial effect for only 10 irrigations.

Gypsum is commonly used as an amendment in reclaiming sodic soils. It also is used to improve water penetration in nonsodic soils, either by lowering the sodium adsorption ratio (SAR) of well water used for irrigation or by increasing the soluble salt content of naturally pure (1 milliequivalent or less per liter) irrigation water. These pure waters, largely from snowmelt, cause dispersion of soil clays and consequent sealing of soil surfaces. Most river water in the Central Valley is of this type, and some well waters approach it.

Granular or powdered gypsum is most commonly spread on the soil surface at a rate of a ton or more per acre once a year. Application in winter or early spring is not recommended, because rainfall or early irrigation may diminish its effect before it is really needed during the high-evapotranspiration months of June to August. Nor should gypsum be incorporated, because its effect is greatest when it remains on the soil surface.

Gypsum is believed to be more efficient when dissolved in low concentrations in irrigation water than when spread on the soil surface. Most of the improvement in infiltration is achieved by the addition of about 3 milliequivalents of the salt per liter of irrigation water, whereas surface-applied gypsum could theoretically dissolve up to its saturation solubility of 28 milliequivalents per liter. More spread gypsum than necessary could thus dissolve in the earlier irrigations, leaving an inadequate supply for later ones.

Devices to dissolve gypsum in water, however, have been cumbersome and have provided inaccurate delivery of the material, so that most growers have gone back to surface-spreading of granular gypsum. A new machine has been developed that more accurately produces a desired gypsum concentration. Water and finely ground gypsum are placed in the machine's 200-gallon tank. An agitator creates a slurry, which is pumped into the main stream of irrigation water at a controlled rate that will give a final concentration of 3 to 5 milliequivalents per liter. The gypsum slurry dissolves immediately in the irrigation stream, whether it is injected into a pressure line to a drip or sprinkler system, or run into open water in a ditch or border.

Orchard experiment

We compared the effectiveness and duration of surface-spread gypsum with that of

TABLE 1. Infiltration amounts and efficiencies

Irrigations	Actual infiltration (inches/ irrigation)	Application efficiency (% of applied water)
1 - 6	**Average of 18 measurements**	
Surface-spread gypsum	1.25 a	86.4 a
Dissolved gypsum	1.19 b	82.1 b
Dissolved calcium nitrate	1.19 b	81.9 b
Control	1.07 c	74.6 c
7 - 10	**Average of 12 measurements**	
Dissolved calcium nitrate	1.25 a	92.6 a
Surface-spread gypsum	1.17 a	86.8 ab
Dissolved gypsum	1.17 a	86.3 b
Control	1.03 b	77.8 c
11 - 15	**Average of 15 measurements**	
Dissolved calcium nitrate	1.32 a	89.5 a
Dissolved gypsum	1.30 a	88.5 a
Surface-spread gypsum	1.17 b	81.1 b
Control	1.06 b	73.9 c

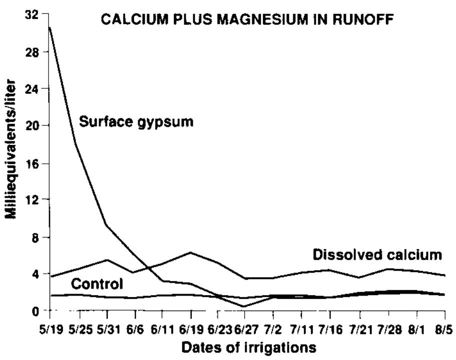

Fig. 1. Surface-applied gypsum saturated runoff from first irrigation, then levels dropped. Dissolved gypsum and calcium nitrate, here combined, averaged 2.7 milliequivalents per liter more than the control over the season.

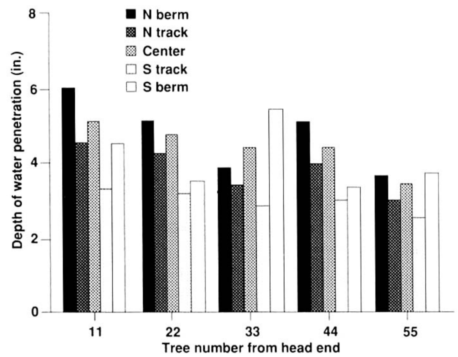

Fig. 2. Regardless of treatment, water penetration was deepest near a berm, intermediate in the center between rows, and shallowest in wheel tracks.

dissolved gypsum using the new machine in a Glenn County almond orchard. In both cases, about 1 ton per acre of gypsum was applied. A third treatment used dissolved calcium nitrate, also applied to the irrigation water to add about 3 milliequivalents per liter. These treatments and a control were replicated three times in a randomized complete block design.

Treatments were applied to individual border checks between two 1,600-foot-long rows of almond trees spaced about 21 feet apart. Trapezoidal flumes at the upper and lower ends of the checks measured total amounts of applied water and runoff, the difference being the amount infiltrated. Water samples were taken at the lower flumes at each irrigation to monitor calcium levels. Irrigation water came from the Sacramento River via Orland-Artois Water District pipelines. Depth of water penetration was measured with a steel probe several times during the season.

Flume measurements were made for two irrigations before any materials were added, with no significant differences among the 12 plots. On May 18, 1987, the surface gypsum was spread, and on May 19 all plots were irrigated, with dissolved gypsum and calcium nitrate applied as two of the four treatments. From this date to August 5, all treatments were irrigated 15 times, with the two dissolved calcium materials added continuously during each irrigation. Intervals between irrigations were mostly 4 to 6 days, and an average of 1.4 inches of water was applied per irrigation.

Runoff and infiltration

Runoff from the first irrigation was saturated with gypsum in the surface-spread treatment (more than 30 milliequivalents per liter of calcium and magnesium), but amounts dropped by almost half at each of the next four irrigations (fig. 1). The level was below that of the dissolved calcium treatments by the fifth irrigation and near the average control level by the eighth irrigation. Meanwhile, the dissolved gypsum, calcium nitrate, and control averaged about 3.9, 4.1, and 1.3 milliequivalents per liter, respectively, over the 15 irrigations.

We had anticipated that the infiltration rate for the surface-spread treatment would drop to near that of the control once the gypsum had completely dissolved at the soil surface, as shown by the lack of gypsum in the runoff. However, that did not happen as fast as we expected. In fact, significantly more water and a greater percentage of the water applied infiltrated in the surface-spread treatment than all other treatments for the first six irrigations (table 1). At the same time, the dissolved calcium treatments were significantly higher in infiltration quantity and percentage than the control.

For the seventh to tenth irrigations, infiltration in the surface-spread treatment remained equal to that in the dissolved calcium treatments. Up to this point, about 14 inches of water had been applied, more than triple the amount needed to dissolve 1 ton per acre of gypsum.

Finally, in the last five irrigations, the infiltration quantity of the surface-spread treatment dropped to near that of the control. It was still higher than the control, however, in percentage of applied water infiltrated.

The depth of water penetration measured with the steel probe paralleled the infiltration results and emphasized the severe water penetration problem in this orchard. The first probe measurements after the third irrigation showed the water to have penetrated slightly deeper in the surface-spread gypsum treatment than in the others (table 2). Water penetration was shallowest in the control plots. By the eighth irrigation, penetration depth in the surface-spread gypsum plots was less than that in the dissolved calcium treatments, but still greater than the control. After 13 irrigations, penetration depths for the surface-spread gypsum plots were closer to the control than to the dissolved treatments.

Depth of water penetration was also affected by the location along the tree row and the position across the interrow. In general, the tree 11 location at the upper end of the check had the deepest penetration, and tree 55 the shallowest (table 2). A change in irrigation management could improve this picture (see Conclusions). Figure 2 shows the penetration depths of all treatments averaged for the five probe positions across each interrow. The deepest water penetration was generally near the berms, with one often deeper than the other because of small

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TABLE 2. Depth of water penetration at three dates and five tree intervals

	Water penetration depth*					
	Tree number					Average per treatment
Dates	11	22	33	44	55	
	inches					
6-2-87, after irrigation 3:						
Dissolved calcium nitrate	4.0	4.0	4.4	4.8	3.6	4.2
Dissolved gypsum	5.2	4.8	4.0	4.0	2.4	4.1
Spread gypsum	4.4	4.4	4.0	5.6	4.0	4.4
Control	4.4	3.2	3.2	2.4	2.4	3.1
Avg per interval	4.5	4.1	3.9	4.2	3.1	
6-25-87, after irrigation 8:						
Dissolved calcium nitrate	6.0	5.2	5.6	4.8	4.0	5.1
Dissolved gypsum	6.8	5.6	4.8	4.4	2.8	4.9
Spread gypsum	5.2	4.4	4.8	4.8	4.0	4.6
Control	4.0	4.0	3.6	3.2	2.4	3.4
Avg per interval	5.5	4.8	4.7	4.3	3.3	
7-23-87, after irrigation 13:						
Dissolved calcium nitrate	6.8	6.8	6.4	5.2	5.6	6.2
Dissolved gypsum	7.2	7.2	6.4	5.2	4.0	6.0
Spread gypsum	5.2	4.4	5.6	4.0	4.8	4.8
Control	5.2	4.8	4.8	3.6	3.6	4.4
Avg per interval	6.1	5.8	5.8	4.5	4.5	

* Each number is an average of 45 readings: 3 readings X 5 positions across interrow X 3 replications.

meet the shortage number would additional registration be announced. If the top-priority group were from 1 to 50,000 smaller than the shortage number, applications would be accepted only from aliens currently residing in the United States whose qualifying agricultural work was in SAS. If the difference were greater than 50,000, all eligible aliens residing in the United States could apply. At a difference greater than 200,000, registration would be extended to all eligible aliens, including those living outside the United States.

The lists of denied SAW applicants and additional registrants would be randomly ordered, except that spouses and unmarried children of aliens legalized under IRCA would have priority within each group. Aliens would be invited to interview and petition for RAW status in the order in which they appeared on the resulting master list. If the proposed registration priority is sustained in the final rule, RAW-eligible aliens who have remained illegally in the United States will be higher on the list, ironically, than those who left when they became ineligible for employment.

Conclusion

For the first two years of IRCA implementation, the new legalization programs and hiring rules diverted most attention from the law's other major provisions affecting farm labor supply. With possible admission of replenishment agricultural workers only a few months away, farm employers and government administrators are facing the formidable task of gearing up for the RAW program. They are generating and processing a tremendous amount of labor market information.

Determinations of how many RAWs to admit each year, from fiscal 1990 through 1993, will rely heavily on data provided by employers to the USDA, DOL, and Committee for Employment Information on Special Agricultural Workers. Even imperfect compliance with the new reporting obligation and uneven participation in the voluntary surveys will greatly enrich the stock of information about farm employment and the influence of legal status on occupational choice. As concern mounts about future farm labor supplies and the impact of IRCA on California agriculture, data collected for RAW program administration will hold great interest for agricultural employer and labor groups as well as the research community.

Howard R. Rosenberg is Cooperative Extension Specialist, Agricultural Labor Management, Department of Agricultural and Resource Economics, University of California, Berkeley.

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differences in grading. Water penetration was shallowest in the wheel track positions, and intermediate at the interrow center position.

Conclusions

The increases in infiltration quantity and water penetration depth resulting from all of the calcium-added treatments were encouraging, but certainly not of great magnitude and less than we had hoped for in this experiment. We had hoped for 100% increases. Two related factors may have contributed to the lack of a greater difference between control and calcium treatments. One is the relatively steep grade, 0.4%, of the border checks, and the other is the length of set, 14 hours. A gentler grade and a longer set, allowing a longer opportunity time for infiltration, perhaps would have magnified the difference between control and calcium treatments. Even with the 0.4% grade, a cutback of water application at some point and extension of the length of set might have provided more infiltration and deeper penetration, particularly at the lower end of the checks.

Among the calcium treatments, the surface-spread gypsum surprised us by remaining effective for several irrigations after it had apparently all been dissolved. This finding implies that high concentrations in the early irrigations are not as wasteful as it would first appear. They may have a favorable effect on soil structure that deteriorates only slowly after the gypsum is gone, as long as the soil surface remains undisturbed.

The gypsum-dissolving machine worked well in adding approximately 3 milliequivalents per liter to the irrigation water. The calcium nitrate solution was easily prepared and applied, but more research is needed to determine if this substantial nitrate addition (180 pounds nitrogen per acre) is equivalent to conventional fertilization. Runoff flows should be recycled to prevent environmental pollution by nitrate.

William E. Wildman is Extension Soils Specialist, Emeritus, Department of Land, Air and Water Resources, University of California, Davis; William H. Krueger is Farm Advisor, UC Cooperative Extension, Glenn County; and Richard E. Pelton is Staff Research Associate, LAWR Soil Extension, UC Davis.

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However, calculation of costs and benefits for low-input systems not yet in full operation is much more difficult.

Consumer benefits of chemical use within the food system include (possibly) increased quality and quantity of food, lower prices, and increased availability of perishable foods over longer periods. An example is the health benefits of having a year-round supply of fruits and vegetables available in many parts of the world. Costs to society may include consumer health risks from residues on crops, exposure of farm workers to contaminants, degradation of underground aquifers and waterways. Quantification of these effects is difficult, since both market and nonmarket evaluations are involved.

Further, we need to understand what policies are appropriate when social benefits do not exceed or equal social costs. The impacts of any regulation usually extend far beyond its intended purpose. And conflicting regulations currently plague the food industry in the United States.

Increasingly, we are receiving signals that our high-technology, energy-intensive agricultural system has not only not sustained productivity, but is causing troublesome environmental problems and exerting pressure on the resource base. These concerns have not been translated into quick action and change. Legislation in the United States has been passed at the state and federal level aimed mainly at some of the environmental issues without consideration of the total problem. Many farmers express interest in adopting low-input practices, but so far change has not been widespread for a variety of reasons—lack of knowledge, risk of decreased profitability, fixity in existing investments. Farmers can't be expected to bear all the costs when they can claim only a share of the perceived environmental benefits.

In summary, there is considerable interest—even deep concern by some groups—and support is growing for action and change. Agricultural academic institutions and the U.S. Department of Agriculture are making a good beginning in researching sustainable agriculture. Every indication is that the pace will be accelerated in the near future. But we don't have sufficient information on farm, regional, or global impacts of the changes that will ensue. The current agricultural system evolved over considerable time, and with some "nudging and pulling," we can eventually tilt it in a different trajectory. However, the rhetoric vastly exceeds our knowledge at this time.

Harold O. Carter is Director, Agricultural Issues Center, and Chair, Department of Agricultural Economics, University of California, Davis.