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PROJECT TITLE: Water management on slowly permeable soils: mechanisms of surface sealing, infiltration characterization, and ameliorative practices

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ABSTRACT:

Three field studies were conducted at the U.C. Kearney Agricultural Center on soils that are predominately Hanford sandy loam (coarse-loamy, mixed, nonacid, thermic Typic Xerorthents). The investigations are directed to improving the understanding of infiltration rate limiting mechanisms and to the development of management systems that improve water infiltration of soils that are either furrow, basin, or drip/trickle irrigated.

Maintaining a clean-tilled condition in a furrow-irrigated 'Thompson Seedless' grape vineyard resulted in a dramatic water infiltration rate decline following the first irrigation of the growing season in both 1987 and 1988. A system of maintaining a continuous growth of brome grass of herbicide treating the grass, but leaving it undisturbed maintained a high, stable infiltration characteristic throughout the season in both years. A residual carry-over effect of the continuous brome grass from 1987 to 1988 was observed. Scanning electron microscope micrographs and water stable aggregate determination provided direct mechanistic evidence for treatment responses.

Modification of the point source position in a drip/trickle irrigation system in a Thompson Seedless vineyard by releasing water 30 cm below the surface improved the distribution of water in the soil profile. Plant water relations and yields were improved by subsurface treatments.

Studies were completed on large basin infiltrometers to evaluate infiltration measurement procedures and surface added soil amendments.

KEYWORDS: furrow irrigation, drip/trickle irrigation, field infiltrometers, water intake functions, soil particle aggregation, crusting

PROJECT OBJECTIVES ADDRESSED:

The central objective of this study was to achieve improved irrigation water penetration for agricultural production systems. This was done by specific directed objectives that include:

1) identification of site specific mechanisms responsible for restricted water penetration,
2) evaluation of different techniques for characterizing the infiltration function based on accuracy and reproduceability, and
3) develop management schemes and evaluate promising additives for improved vertical water flow into soils.

RESEARCH PLAN AND PROCEDURES:

Water infiltration is frequently observed to become severely restricted as the growing season progresses for many eastern San Joaquin Valley soils. Plant water deficits develop during periods of moderate to high potential transpiration. Affected soils include those devoted to perennial tree and vine crops where losses reach or exceed $1200 per hectare (LAWR-Cooperative Extension Joint Infiltration Committee, 1984). Estimates indicate that more than one million hectares are affected by restricted irrigation water infiltration in California.

The work done on this project consisted of two major field experiments and one study directed to evaluating the methodology of measuring infiltration under field conditions. All studies were done at the U.C. Kearney Agricultural Center on soils that were mostly Hanford sandy loam (coarse-loamy, mixed, nonacid, thermic Typic Xerorthents). This soil is representative of many eastern San Joaquin Valley soils having restricted water infiltration.

Vineyards furrow irrigation

A two-hectare vineyard was utilized in this study. Six treatments:

T-1 = Control; clean till

T-2 = Brome grass; continuous

T-3 = Brome grass; herbicide

T-4 = Brome grass; incorporate and then clean till

T-5 = Gypsum; surface apply one time annually

T-6 = Gypsum; irrigation run

are replicated three times in a randomized complete-block design. A single zone between standard width, 3.7-m vine rows served as a plot, vine rows (and plots) were 260 m long. An individual, buried, 15-cm PVC line was installed at the field site to provide head control of the water supply. Individual plot water meters provided for water furrow-inflow measurement. Characterization of intake functions was by a volume-balance approach (Elliott and Walker, 1982; Goldhamer and Peterson, 1984).

Drip/trickle irrigation

A two-hectare 'Thompson Seedless' vineyard was utilized for this study. Treatments that were evaluated are:

T-1 = Control; above ground emitters

T-2 = Buried system; entire lateral/emitter system was buried 30 cm below the soil surface

T-3 - Bury; spaghetti tube only from the above-ground emitter outlet into a cylindrical (5 cm diameter x 10 cm high) mulch (almond shells) 25 cm below the soil surface

T-4 - Surface-gypsum injection

T-5 - Subsurface-gypsum injection through the spaghetti tubing 30 cm deep

These treatments were replicated three times in a randomized complete block design. Each plot consisted of 3-rows, 59 m long, spaced 3.7 m apart.

Nine neutron probe access tubes were placed in each plot and monitored approximately every ten days. Both horizontal and vertical distribution of soil water was measured from the emitter water source.

A near saturated gypsum solution was injected into the T-4 and T-5 treatment water supply. The injector system consisted of an injector, 190L capacity reservoir, water supply control value assembly for the reservoir, and time clock-meter devices.

Required water additions to meet nonstressed, crop evapotranspiration (ET_{crop}) were determined from a crop coefficient (K_c) and potential evapotranspiration (ET_o from a CIMIS station near the field site) on a weekly basis. Calculations were initiated in late March following budbreak and irrigations were started in early April. Potential crop evapotranspiration (ET_{oc}) determined from $ET_{oc} = k_c \cdot ET_o$, and applied water for 1988 are illustrated in Fig. 1. Details of the procedure are given by Grimes and Williams (1989).

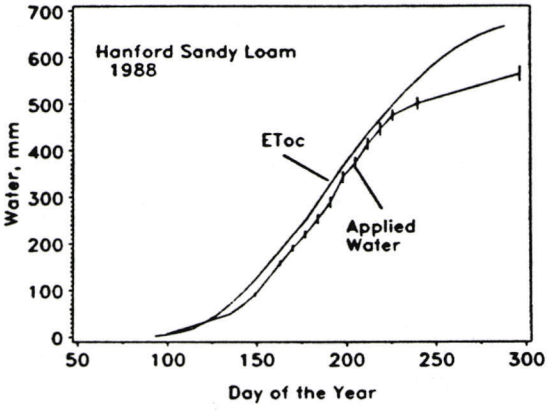


Fig. 1. Seasonal potential crop evapotranspiration (ET_{oc}) and mean applied water for five treatments. Vertical bars are standard errors for water additions of the five treatments.

Field infiltrometers

Sixteen field infiltrometer units were constructed to evaluate:

T-1 - Single ring-control

T-2 - Single ring-gypsum added at each irrigation event

T-3 - Single ring-organic residue incorporated in the surface

T-4 - Single ring-PVA surface stabilizer

T-5 - Double ring-control

T-6 - Double ring-gypsum

T-7 - Flowing furrow-control

T-8 - Flowing furrow-gypsum

Each of the eight treatments was duplicated in a randomized complete block field plot design. The "single ring" unit was 3 m x 3 m of 1" x 12" lumber treated and sealed at the edges to form a water tight basin. Trenches were dug to leave about 20 cm of basin wall above the ground surface. The inner-rings of the double-ring units were identical to single ring units. An additional outside ring was constructed and installed in a like manner leaving 45 cm between outside and inside components. Flowing furrow units, with similar dimensions to basins, consisted of six furrows spaced at 0.75 m intervals.

Grain sorghum was seeded to all plots in both 1987 and 1988 to deplete antecedent moisture to a common level prior to imposing treatments. For infiltration measurements, basins were filled rapidly by a water source plumbed to individual plots. After filling to the desired head, the water supply was switched to a large Mariotte reservoir assembly equipped with both sight tubes and pressure transducers for inflow measurement. A flowing furrow device (Walker and Willardson, 1983) was constructed and used for furrow plot evaluation. Two infiltration cycles were done in 1987 and three cycles were completed in 1988.

Samples have been collected from plots for scanning electron microscope (SEM) (Onofiok and Singer,1984) and aggregate stability analysis.

RESULTS AND DISCUSSION:

Vineyard furrow irrigation

A time advance function of the form,

$$d = ae^{bt} - a,$$

was used to select two time (one-half and full) advance parameters for the volume balance model of Elliott and Walker (1982). In this function d is distance of advance, t is time, and a and b are statistically derived constants; all three replications were used to develop this function for each treatment of the study. The expanded Kostiakov equation (Clemmens, 1983) defines the infiltration functions.

Considerable carry-over effects, of treatments initiated in the spring of 1987, to 1988 were shown. Figure 2 illustrates this by comparing a clean-till treatment with an herbicide treated brome grass system. Virtually no change in the cumulative intake curve from 1987 to 1988 was shown for the clean-till treatment, however, a substantial increase in intake was observed for the brome grass system.

Figure 3 illustrates the primary treatment-time trends for water intake characteristics observed in 1988. The incorporated brome grass and water run gypsum treatments are not shown, but they were essentially the same as for the annual gypsum treatment. Continuous and herbicide treated brome grass began the season with a very high water intake characteristic. Although a decline was observed during the season, a very acceptable infiltration property was maintained through the fifth and final irrigation of the growing season. The clean-till system was characterized by a reasonable water infiltration in early season, but by season end infiltration declined to a marginal level to effectively meet evapotranspirational demand. Table 1 contains the derived parameters (a and k) and the input steady-state (after 8 hours) infiltration rate appropriate for the various functions of Fig's 2 and 3. The c values reflect measurements made in each plot using a flowing furrow technique (Walker and Willardson, 1983).

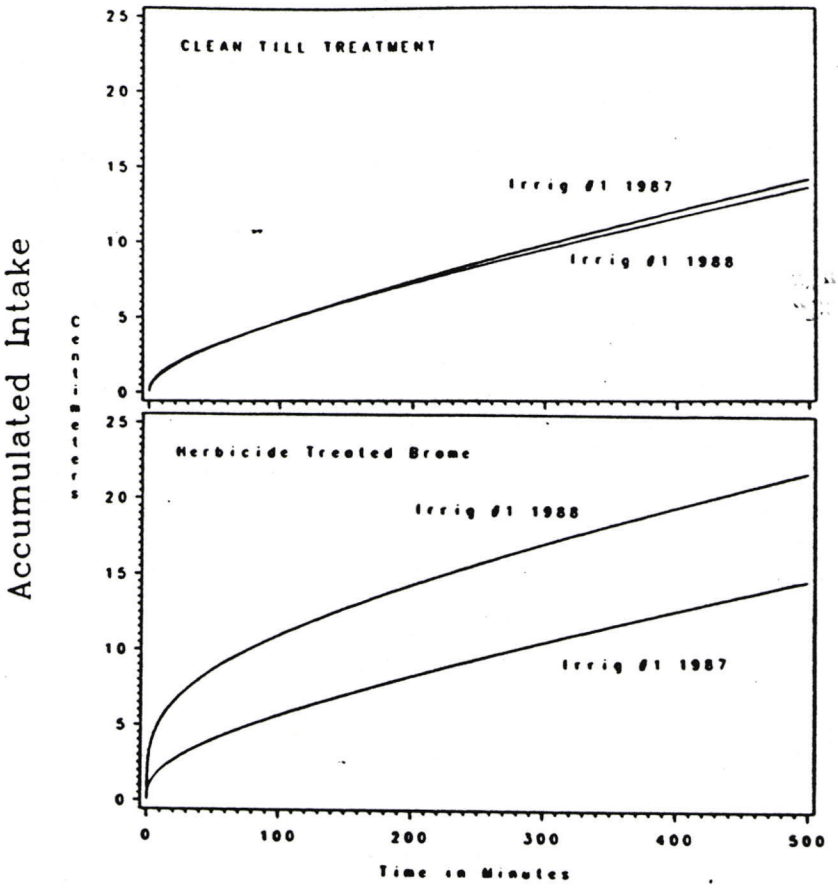


Fig. 2. Carry-over effects of a brome grass treatment initiated in 1987.

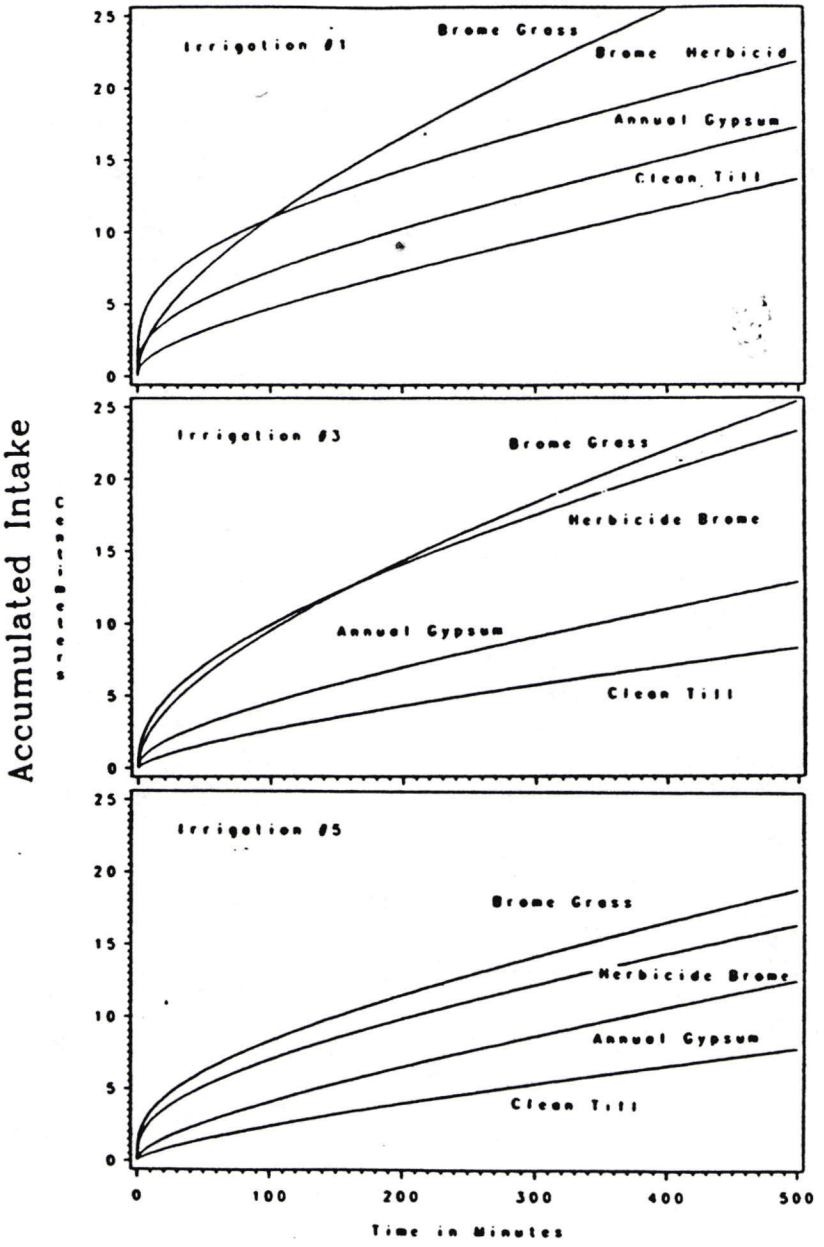


Fig. 3. Comparison of cumulative water intake functions for clean-till, gypsum, and brome grass systems in 1988.

Table 1. Numerical parameters for the expanded Kostiakov equation shown graphically in Figs 1 and 2.

Expanded Kostiakov parameter	Clean till	Annual gypsum	Herbicide brome	Continuous brome
		Irrig. #1 1988		
a	0.4123	0.3307	0.2612	0.5234
k	0.1897	0.4976	1.119	0.3348
c	0.0058	0.0058	0.0058	0.0058
		Irrig. #3 1988		
a	0.6486	0.4516	0.4135	0.5014
k	0.0444	0.1632	0.5029	0.3139
c	0.0015	0.0047	0.0052	0.0058
		Irrig. #5 1988		
a	0.6615	0.5117	0.3412	0.3244
k	0.0384	0.1085	0.4659	0.6040
c	0.0015	0.0047	0.0052	0.0058
		Irrig. #1 1987		
a	0.4637	-	0.3490	-
k	0.1501	-	0.3296	-
c	0.0058	-	0.0052	-

0.35 in/hr cont. Brom
0.31 in/hr Herb Brome
0.09 in/hr clean Till

The expanded Kostiakov equation has the general form $d = kt^a+ct$ where d is accumulated infiltered water (inches for the given parameters, but converted to cm in Figs. 2 and 3), t is time in minutes, a is a derived dimensionless parameter, c is a steady state intake rate (in/min), and k is a derived proportionality constant whose units are in/min^a.

Our last year's report (Grimes et al., 1988) contained SEM micrographs that clearly illustrated a much more open surface condition for brome grass systems. Figure 4 shows that brome grass, especially grown continuously, increased the proportion of water stable aggregates as measured with the procedure of Kemper and Rosenau (1986).

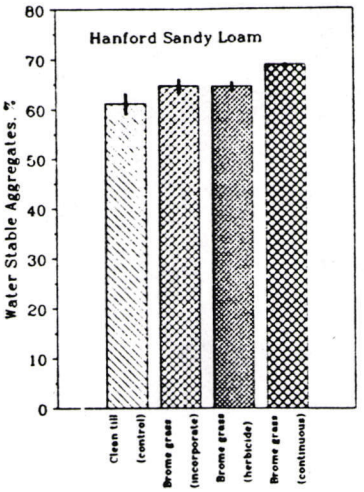


Fig. 4. Influence of clean-till and brome grass systems on water stable aggregation of a Hanford sandy loam after six irrigations in 1987. Vertical bars are treatment standard errors.

Drip/trickle irrigation

A gypsum injection system was constructed during 1987, but only fully implemented in 1988. In 1988, buried water injection systems and gypsum substantially increased subsurface soil water content over the above-ground control treatment (Grimes et al., 1988). On this slowly permeable soil the surface (control) gave a larger wetted surface area, compared with emitters below the surface, that probably resulted in a higher evaporation component for ET. The 1987 production was not affected by the treatments. However, both subsurface residue and subsurface gypsum treatments had higher average yields in 1988 than did the control (surface) treatments (Table 2). Berry weight at harvest was not influenced by point source treatment nor was any of the measured quality parameters.

Table 2. Water release position and gypsum injection effects on grape yield, berry weight, °brix, pH, and titratabe acidity (TA) in 1988.

Treatment	Yield, t/ha	Berry wt., g	°Brix	pH	TA
T-1 Control	22.214 a*	1.55 a	21.1 a	3.66 a	0.47 a
T-2 Subsurface lateral	22.273 a	1.55 a	21.1 a	3.60 a	0.46 a
T-3 Subsurface residue	23.772 ab	1.52 a	21.0 a	3.61 a	0.47 a
T-4 Surface gypsum	22.291 a	1.61 a	21.0 a	3.64 a	0.47 a
T-5 Subsurface gypsum	25.676 b	1.54 a	20.7 a	3.58 a	0.47 a

* Means in columns not followed by the same letter differ at a 0.05 probability level using Duncan's test.

Figure 5 shows that the petiole concentration just before harvest in 1988 was reduced substantially for all subsurface water treatments (T-2, T-3, and T-5) compared to a surface drip irrigation delivery (T-1 and T-4). Also, gypsum injection (T-4 and T-5) reduced K uptake slightly when compared with a no gypsum treatment counterpart (T-1 vs. T-4 and T-3 vs. T-5).

The Hanford soil of this study site has substantially lower exchangeable potassium below 20 cm compared to the surface soil; this phenomenon is fairly typical of eastern San Joaquin Valley soils (Kasimatis and Christensen, 1976). As a result of increased root activity at lower profile depths with buried drip emitters, k uptake was reduced. This problem is receiving additional attention with our current studies.

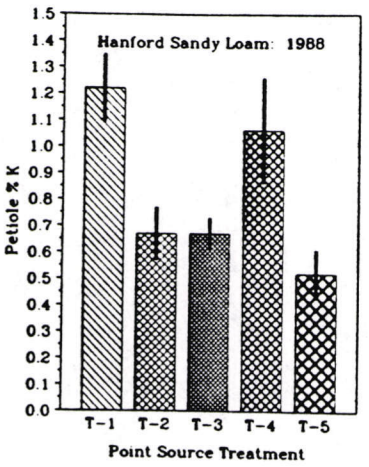


Fig. 5. Surface and subsurface drip irrigation effects on petiole K concentration before harvest in 1988. Vertical bars are treatment standard errors.

Field infiltrometers

Two irrigation cycles were done in 1987 and three in 1988. A computer program has been developed to analyze the data according to the plan of study, but the analysis is not yet completed. Sufficient results have been analyzed, however, to indicate that within study site random soil variability is going to present a problem for data interpretation with the analysis techniques originally planned. We are continuing to explore various alternatives for obtaining meaningful results from this study.

DISCUSSION AND SUMMARY:

Water penetration continues to be a perplexing problem of serious magnitude for California agriculture although many studies have addressed the issue. To be most effective, investigations must evaluate both site specific rate limiting mechanisms of water infiltration and develop possible corrective management practices. Our 1987 and 1988 field studies were directed to accomplishing those goals.

Continuous brome grass or herbicide treated brome grass in a furrow irrigated 'Thompson Seedless' grape vineyard maintained water infiltration properties that allowed adequate water storage to be accomplished at reasonable irrigation intervals throughout the growing season. On-the-other-hand, a clean-till system experienced a rapid decline in water intake properties. Brome grass systems maintained an open soil surface and had a higher proportion of water stable aggregates than did a clean-till culture.

Modification of the point source of a drip irrigation system to achieve water release below the surface improved the subsurface distribution of water in a profile compared with surface positioned emitters. However, increased root activity at lower profile depths resulted in reduced plant K uptake from the low soil K subsurface of the Hanford sandy loam soil. In spite of the reduced K uptake, yields were higher for subsurface positioned emitters.

These studies should improve the understanding and applied aspects of water penetration problems. The unique features of this study site are expected to contribute to broad scale concepts for diagnosing potential problem areas and expanding a data base for possible model development/validation.

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Abstract