AMENDMENT SCREENING FOR INCREASING INFILTRATION RATES IN WARDEN AND RITZVILLE SILT LOAMS

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ABSTRACT

Many potato-producing soils in Central Washington have poor infiltration rates resulting from high exchangeable sodium in the soil or from irrigation water with a high sodium adsorption ratio (SAR), low electrolytic conductivity (EC) or both. Many amendments have been recommended for improving the IR of a soil ranging from gypsum to polymeric surfactants. Our objective was to develop a laboratory apparatus which could determine reproducibly the infiltration rate of a soil subjected to water from an overhead sprinkler. We then determined infiltration rates of two soils after application of a number of amendments, including gypsum, polyacrylamide (PAM), Wet-Sol, acidified or salted water, compost, and straw. Compost and straw were the most effective amendments because they provided a physical barrier to the sprinkler drops, inhibiting surface sealing. Of the chemical treatments PAM and water with a high EC (1.9 ds/m) and low SAR (1.0) were both effective, but PAM was more effective when applied to soil with top-dressed gypsum. The other chemical treatments, gypsum alone, acidified irrigation water, and Wet-Sol, were all better than the control. Soil acidified with sulfuric acid before irrigation was only slightly better than the control in the more calcareous Warden soil. In the Ritzville soil, acidification had no significant effect after three applications or irrigation water.

INTRODUCTION

In conversations with growers, extension agents, and consultants in central Washington, it has become apparent that reduced infiltration rates in soils receiving water from overhead sprinklers is an ongoing and worsening problem for some potato growers. Gypsum ($CaSO_4 \cdot 2H_2O$) is the conventional treatment for this problem because it raises the electrolytic conductivity (EC) while lowering the sodium adsorption ratio (SAR) of the soil water. A high EC and low SAR both serve to improve soil structure by inhibiting swelling and dispersion of soil clays. The fact that gypsum must be applied regularly to be effective coupled with its increasing expense (about $160 per ton), led us to conduct a search for alternative amendments and treatments to increase infiltration rates.

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Surface sealing of soils is caused by drop impact, but is enhanced by water with a high SAR and low EC. Increasing the amount of Ca and the total salt concentration in irrigation water has been shown to increase infiltration rates. Sulfuric acid has been shown to be more effective than gypsum in the reclamation of sodic soils that are also calcareous (Miyamoto, 1977; Yahia et al., 1975). Commercial cationic and anionic polymers are showing promise as soil conditioners which can increase infiltration and hydraulic conductivity even when applied at low concentration (Ben-Hur et al., 1989). When used in combination with gypsum these polymers have been even more effective.

The objectives of this research were (1) to develop a small-scale sprinkler that could be used in the laboratory to determine infiltration rates following overhead water application; and (2) to utilize the sprinkler to screen a number of amendments that have potential for improving soil infiltration. We found that a reproducible method of determining infiltration rate could be applied to several promising amendments which either provide a physical barrier to the falling water droplets or chemically improve the soil's ability to resist dispersion.

MATERIALS AND METHODS

Two soils shown to have low infiltration rates were selected for the study. A Warden silt loam, located 1/2 mile east of Quincy had a pH of 8.06, an EC of 6.7 dS/m, and a carbonate percentage of 1.19. A Ritzville silt loam was collected four miles north of Prosser and had a pH of 8.54, EC = 1.06, and carbonate = 0.20%. Water analyses from deep wells used to irrigate these soils were used to make a simulated "well" water for the control and soil-amended treatments. The analyses of well and simulated water are shown in Table 1.

Infiltration rate was determined with a newly constructed rainfall simulator which can control application rate, drop size and impact, and water quality. The simulated water composition was the same as in Table 1, except where the "amendment" consisted of varying the pH or EC and SAR of the applied water. The water was applied to air-dry soil packed to a bulk density of 1.2 - 1.3 g/cm^3 in metal trays tipped at a 5% slope and runoff was collected in a graduated cylinder. Infiltration rate was calculated by subtracting runoff from application rate (90 ml/min). A minimum of 3 irrigations were made for each amendment on each soil to determine how the amendments affected irrigation rate with successive irrigations. Soils were dried to a moisture content of 12 $\pm$ 4% between irrigations.

Amendments or treatments were appplied as follows:

Untreated control	Soil crushed and sieved to 2 mm
Gypsum	Applied to soil surface @1000 lb/Ac
PAM	Applied in irrigation water @2.5 ppm
EC=1.9/SAR=1.0	Irrigation water adjusted with $CaCl_2$

pH=3.5 and pH=5.4	Irrigation water adjusted with H_2SO_4
Acidified soil	Soil surface pH lowered to <6.5 with 0.1 M H_2SO_4
Wet-Sol	Applied to soil surface @1 gal/acre
Compost	Added to soil surface @1000 lb/acre
Straw	Added to soil surface @1000 lb/acre.

The gypsum-PAM treatment consisted of applying PAM-treated irrigation water to soil with surface-applied gypsum.

RESULTS

Figure 1 shows a typical set of three runs on the untreated Warden silt loam. In the first run, the surface seal forms during the irrigation and the soil is slow to pond. The final infiltration rate is less than 0.1 mm/min. In the second and third runs ponding occurs more rapidly because the seal was formed already in the first run. The final infiltration rate is lowest in the third run.

The effect of gypsum application to the Warden loam is shown in Figure 2. Ponding begins near 15 mm of applied water compared to 10 mm without gypsum. Ponding is delayed and the final infiltration rate is greater in both the second and third runs compared to the control. Figures 3 and 4 show that gypsum is more effective on the Ritzville soil because, with its lower initial EC, it has a greater problem with sealing when untreated. Thus, the gypsum makes a larger difference, increasing both the EC and Ca in this soil.

The application of PAM and gypsum + PAM to the Ritzville was followed for four runs (Figures 5 and 6). Polyacrylamide is somewhat more effective than gypsum alone in delaying ponding times in the successive runs and gives comparable final infiltration rates. Combining the two treatments resulted in longer times to form the surface seal and some improvement in the fourth run over the second and third. Figure 7 shows a summary of the third run results for the above treatments on the Ritzville as well as surface-applied compost. Compost is the most effective amendment both in terms of delaying the seal formation and the final infiltration rate because it acts as a barrier to soil dispersion by the water droplet impact from the sprinkler. The gypsum + PAM combination is nearly as effective as the physical barrier. In the Warden soil (Figure 8) it can be seen that gypsum makes little improvement and PAM used alone is almost as effective as the combination. Compost improved the time to ponding (surface sealing) but did not improve the final infiltration rate significantly in the third run.

Figures 9 and 10 summarize the third run data for the Warden and Ritzville soils irrigated with water treated to lower pH or increase EC. In the Warden both the EC=1.9 and pH=5.4 treatments delayed ponding. The pH 3.5 treatment slightly delayed ponding in the third run but did not significantly effect the final infiltration rate.

In the noncalcareous Ritzville, acidifying the water had little effect, but increasing the EC to 1.9 was very effective in slowing seal formation.

The averaged infiltration rate at the end of a run, obtained by averaging the rates over the last ten sample points, combines the effects of time to ponding and final infiltration rate. This value for runs 1 and 3 are given in Tables 2 and 3 for the Warden and Ritzville soils, respectively. The overall rate for the untreated soil is assigned a value of 100 to facilitate comparisons among treatments. For both soils, compost and straw are generally the most effective amendments both in the short and long term, although PAM+gypsum is a good combination, exceeding straw in overall performance in the Ritzville.

Most of the other treatments are better than the control in the third run with the exception of acidifying the noncalcareous Ritzville with H_2SO_4 which worsened infiltration in the first run and was ineffective in subsequent runs. Wet-Sol had little effect at the start but improved infiltration in the third run. We are continuing to experiment with Wet-Sol treatments at higher rates and with more frequent application. for the low EC Ritzville soil, increasing the EC of the irrigation water was a successful means of increasing infiltration. Polyacrylamide alone was less effective than increasing EC for the Ritzville which helps to explain why combining with gypsum was so effective.

CONCLUSIONS

The results show that a simulated irrigation device can be used to display differences among soil treatments in terms of overall infiltration rate. Comparisons are best made in second and successive irrigation events because some treatments take longer to work, for example PAM, and others are only effective at the beginning, such as low pH water. There was little difference among gypsum, Wet-Sol, and acidified water, but all showed improvement over the control. Gypsum + PAM and PAM alone were better than gypsum alone. The Ritzville responded better to amendments which raised EC, whereas acid treatments were more likely to improve the calcareous Warden. The physical barrier to drop impact supplied by compost and straw tended to give the best overall infiltration rates over time.

Future work will include other amendments such as Iron-sul, higher Wet-Sol application, and a synthetic gypsum which is much less expensive than the commonly used mined gypsum. Field studies will be carried out to determine if results are consistent with the laboratory sprinkler.

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Table 1. Water quality parameters from deep wells used to irrigate Ritzville (A) and Warden (B) soils and from the "simulated" water for the laboratory irrigation.

Water	pH	EC (dS/m)	SAR	HCO_3 (mmol/l)
A	8.9	0.3	8.2	6.00
B	8.8	0.58	6.2	4.43
Lab.	8.8	0.58	6.5	4.40

Table 2. Averaged infiltration rates of amended Warden soil relative to a rate of 100 for the untreated soil.

Treatment	Run 1	Run 3
Compost	180.5	510.8
Straw	175.3	410.8
Gypsum + PAM	140.5	300.5
EC=1.9	119.3	227.4
PAM	106.5	224.8
pH=5.4	127.7	219.8
Gypsum	150.0	159.2
Wet-Sol	148.5	152.9
pH=3.5	160.6	149.7
Acidified soil	129.3	122.3

Table 3. Averaged infiltration rates of amended Ritzville soil relative to a rate of 100 for the untreated soil.

Treatment	Run 1	Run 3
Compost	128.3	502.6
Gypsum + PAM	108.6	443.8
Straw	115.8	400.2
EC=1.9	101.8	366.2
pH=5.4	105.2	233.3
PAM	93.4	176.0
pH=3.5	106.0	163.0
Wet-Sol	98.6	147.0
Gypsum	100.0	144.0
Acidified soil	74.0	106.0

Figure 1. Infiltration rate over three successive runs for the untreated Warden silt loam with simulated well water.

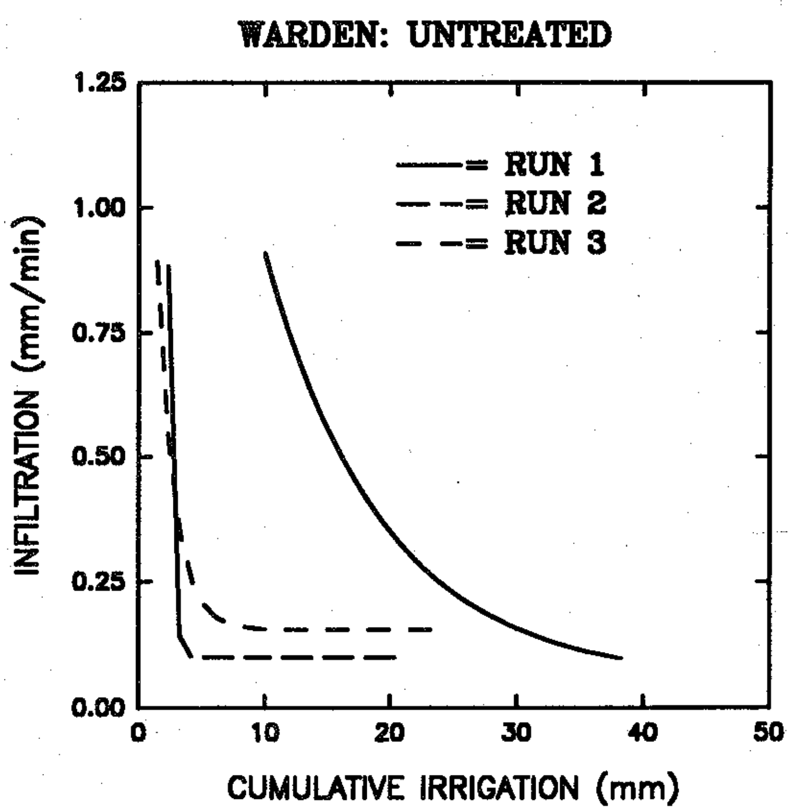

Figure 2. Infiltration rate over three successive runs for the gypsum treated Warden silt loam with simulated well water.

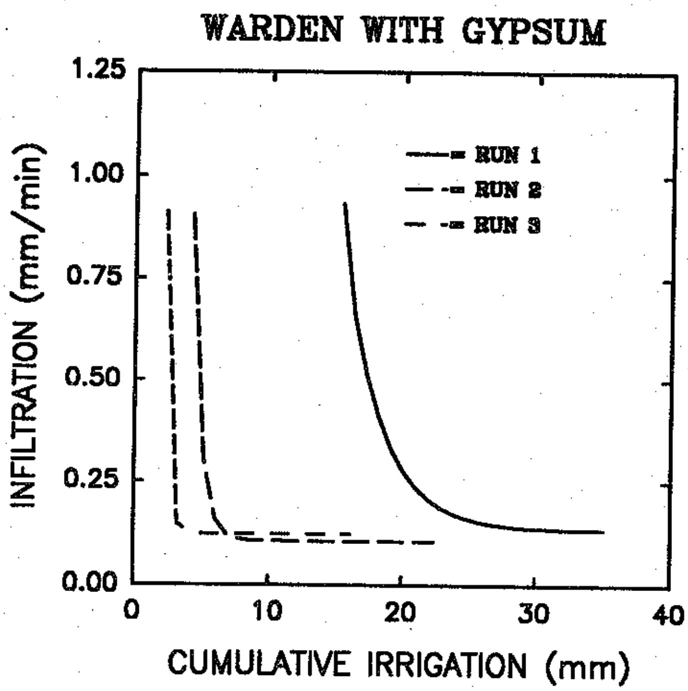

Figure 3. Infiltration rate over three runs for the untreated Ritzville soil with simulated well water.

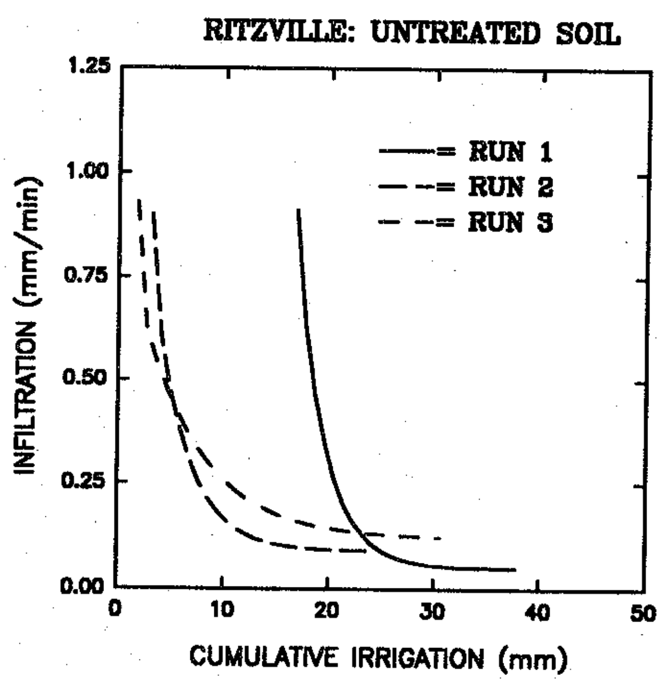

Figure 4. Infiltration rate over three successive runs for the gypsum treated Ritzville silt loam with simulated well water.

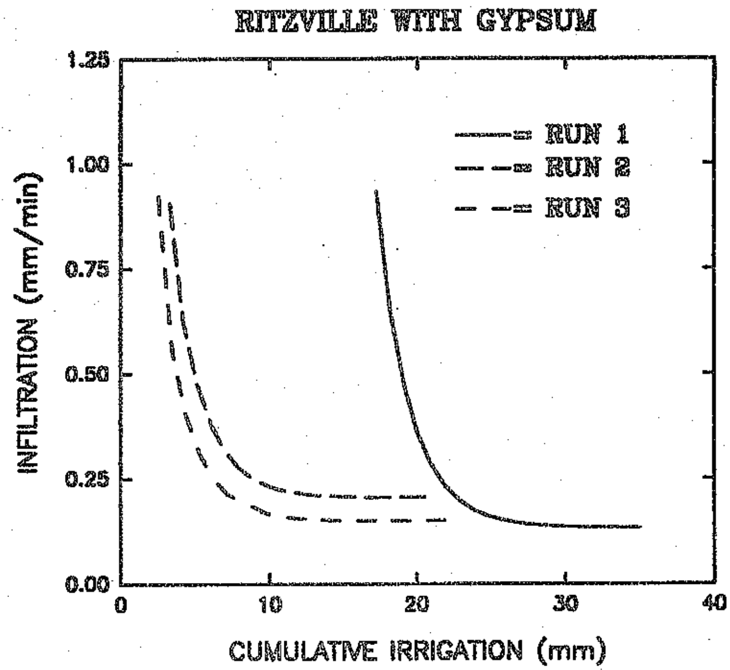

Figure 5. Infiltration rate over four successive runs for the Ritzville silt loam with simulated well water containing 2.5 ppm PAM.

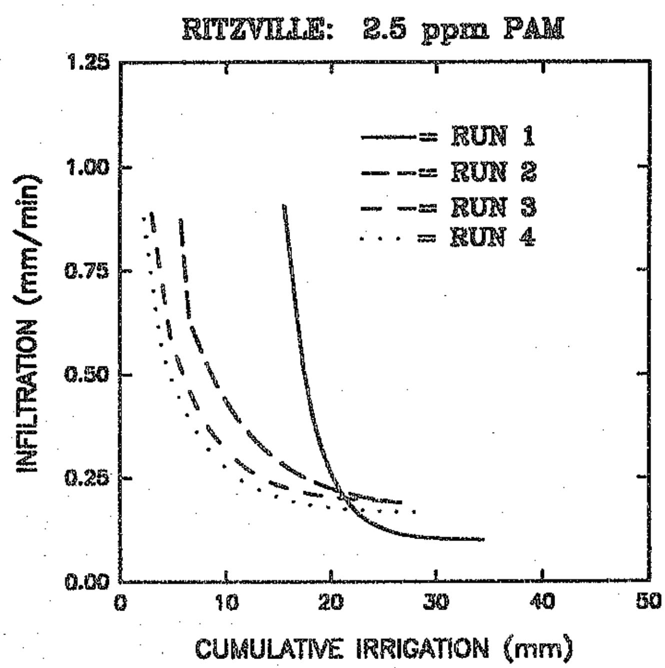

Figure 6. Infiltration rate over four successive runs for the gypsum-treated Ritzville silt loam with simulated well water containing 2.5 ppm PAM.

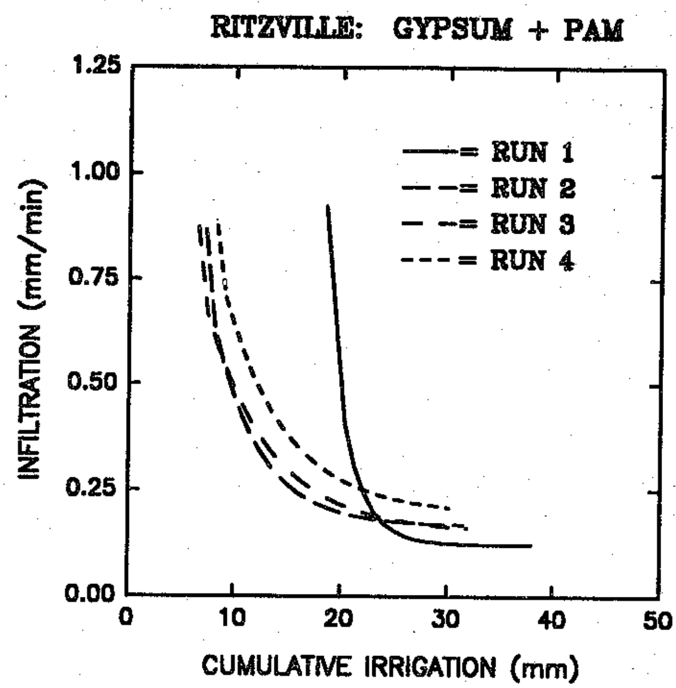

Figure 7. Infiltration rates for the third run after treating the Ritzville soil with compost or gypsum and simulated well water with or without PAM.

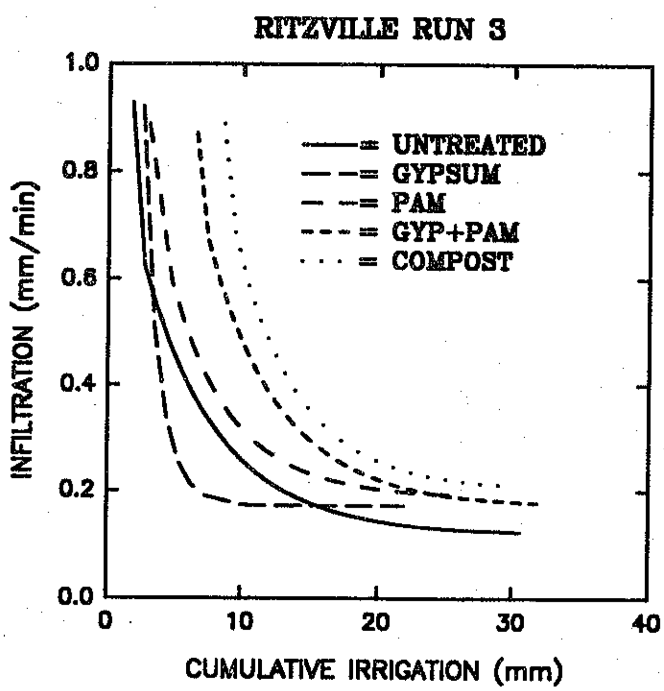

Figure 8. Infiltration rates for the third run after treating the Warden silt loam with compost or gypsum and simulated well water with or without PAM.

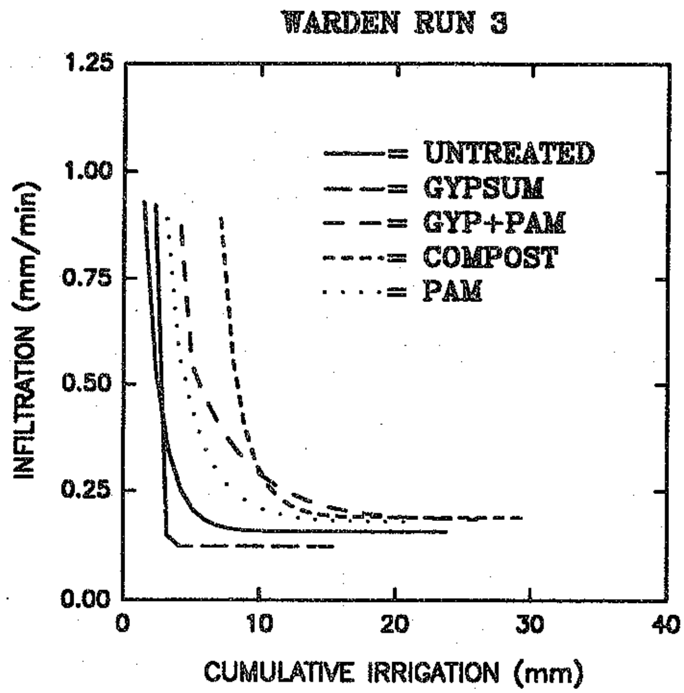

Figure 9. Infiltration rates for the third run on the Ritzville soil using simulated well water containing sulfuric acid or calcium chloride.

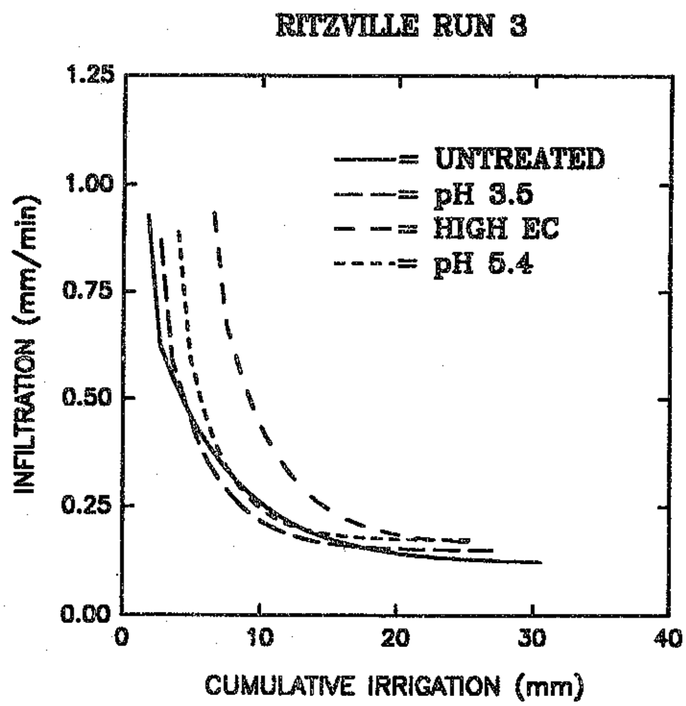

Figure 10. Infiltration rates for the third run on the Warden soil using simulated well water containing sulfuric acid or calcium chloride.