Effect of Fertigation Strategy on Nitrate Availability and Nitrate Leaching under Micro-Irrigation

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Introduction

Micro-irrigation has the potential of precisely applying water and fertilizer both in location and in quantity. Fertigation is the process of applying fertilizers through the irrigation water. However, under micro-irrigation, soil water content, root distribution, and solute concentration vary spatially around the drip line. This variability could result in fertilizer applied through the irrigation system being leached beyond the area of the highest root density unless careful management of both water and fertilizer is practiced.

A recommendation frequently used for fertigation with micro-irrigation is to inject during the middle one-third or the middle one-half of the irrigation set time to insure a field-wide uniformity of applied fertilizer equal to that of the irrigation water and a relatively uniform chemical distribution in the root zone. However, a common practice is to fertigate for a short period of time, i.e. one or two hours, mainly because of convenience. Short fertigation events could result in relatively nonuniform distributions of fertilizer in the soil profile that could affect the availability and leaching of a fertilizer that moves readily with water flowing though the soil. This project investigated the distribution of nitrate in the root zone for various soil types, micro-irrigation systems, and fertigation strategies. A manual on fertigation with micro-irrigation is being developed.

Methods and Materials

The computer simulation model HYDRUS-2D was used to assess the effect of various fertigation strategies on water and nitrate distribution in the soil profile and on nitrate leaching. Outputs of the model include distributions of nitrate and soil water content in the soil profile and a mass balance of nitrate.

Fertigation scenarios evaluated by the model are:

– micro-irrigation systems were 1) SPR - microsprinkler (citrus) using a sprinkler discharge rate of 5 gph; 2) DRIP - surface drip irrigation (grapes) using 1 gph emitters; 3) SURTAPE - surface drip irrigation (strawberries) using drip tape with a tape discharge rate of 0.45 gpm/100ft; and 4) SUBTAPE - subsurface drip irrigation (tomatoes) using drip tape buried at 8 inches deep with a tape discharge rate of 0.22 gpm/100 ft.

– soil types - sandy loam (SL), loam (L), silt clay (SC), anisotropic silt clay (AC) with a ratio of horizontal hydraulic conductivity to vertical conductivity equal to 5.

– fertigation strategies include 1) B – inject for 2 hours starting one hour after start of irrigation, 2) M - inject for 2 hours in the middle of the irrigation set, 3) E - inject for 2 hours starting 3 hours before cutoff of irrigation water, 4) M50 – inject during the middle 50% of the irrigation set time, and 5) C - inject continuously during the irrigation set starting 1 hour after start of irrigation and ending 1 hour before irrigation cutoff. For SURTAPE, injection time for B, M, and E was 0.5 hours.

Assumptions used for the modeling include 1) maximum evapotranspiration conditions and an irrigation efficiency of 85%, 2) an irrigation set time sufficiently long to apply the desired amount of water, 3) no nitrate in the soil profile at the start of simulation, 4) quasi-equilibrium soil moisture content patterns at the start of the fertigation scenarios, and 5) the same amount of nitrogen injected for each scenario.

Results and Conclusions

Nitrate concentrations shown in the Fig. 1 to 4 are relative concentrations, defined as the ratio of the actual concentration in the soil to the concentration in the irrigation water of the 2-hr injection time. The irrigation water concentrations of the M50 and C strategies were adjusted to reflect the longer injection times compared to the 2-hr injection. Nitrate distribution for DRIP (loam) showed a leached zone in the immediate vicinity of the drip line for the B strategy (Fig. 1). Nitrate accumulated near the boundary of the wetted pattern. Nitrate was distributed in the vicinity of the drip line for the E strategy with concentrations much higher compared to the B strategy. The M50 and C strategies resulted in a more uniform nitrate distribution compared to the other strategies. Similar patterns were found for the sandy loam (data not shown).

Nitrate distributions for DRIP (silt clay) differed from those of the loam and sandy loam. Water ponded on the soil surface caused downward water flow instead of radial flow found in sandy loam and loam soil. The downward flowing water resulted in a horizontal band of nitrate for the B strategy (Fig. 2). The E strategy resulted in a narrow zone of nitrate near the surface. Nitrate was dispersed more uniformly in the upper part of the soil profile for strategies M50 and C.

Nitrate distributions for SUBTAPE (sandy loam) showed a zone of leached soil in the immediate vicinity of the drip line for the B strategy with a zone of nitrate beyond the leached soil due to the relatively long irrigation time after fertigation (Fig. 3). For the E strategy, however, relatively high nitrate concentrations occurred in the immediate vicinity of the drip line. Upward movement of nitrate was much higher for the B strategy due to the relatively dry soil above the drip line at the beginning of fertigation compare to the E strategy. Nitrate distributions of the M50 and C strategies showed a more uniform distribution over the soil profile compared to the 2-h fertigation strategies.

Nitrate distributions of SPR reflected the water application pattern of the microsprinkler. Most of the water applied by this sprinkler occurred within about 4 ft from the sprinkler (data not shown). Injecting near the beginning of the irrigation for a short time period leached most of the nitrate down in the soil profile, whereas injecting near the end of the irrigation left most of the nitrate near the soil surface (Fig. 4).

Similar nitrate distributions occurred for SURTAPE for all fertigation strategies except for the E strategy (data not shown). The reason for this behavior was the relatively small irrigation times (3.2 hours) of this scenario. Thus, for the short fertigation events, which were 0.5 h, irrigation times following fertigation were relatively small.

Nitrate moved more in the horizontal direction than in the vertical for the anisotropic silt clay scenarios (data not shown).

Conclusions

In general, less nitrate was leached from the root zone for the E strategy compared to the other strategies for DRIP and SPR. Also, a more continuous fertigation resulted in a more uniform distribution of nitrate in the soil. The results were less conclusive for SUBTAPE. Upward movement of nitrate above the drip line appears to have resulted in little differences in nitrate leaching among the different strategies. Little difference in nitrate leaching also occurred for SURTAPE, mainly because of the short irrigation set time. Nitrate distributions around the drip line were relatively similar for all strategies compared to the other micro-irrigation systems. However, more nitrate leaching occurred for SURTAPE compared to the other micro-irrigation methods, reflecting the shallow root depth, about 12 inches, of the crop (strawberries) used for this scenario. Leaching was the highest for sandy loam compared to the other soil types.

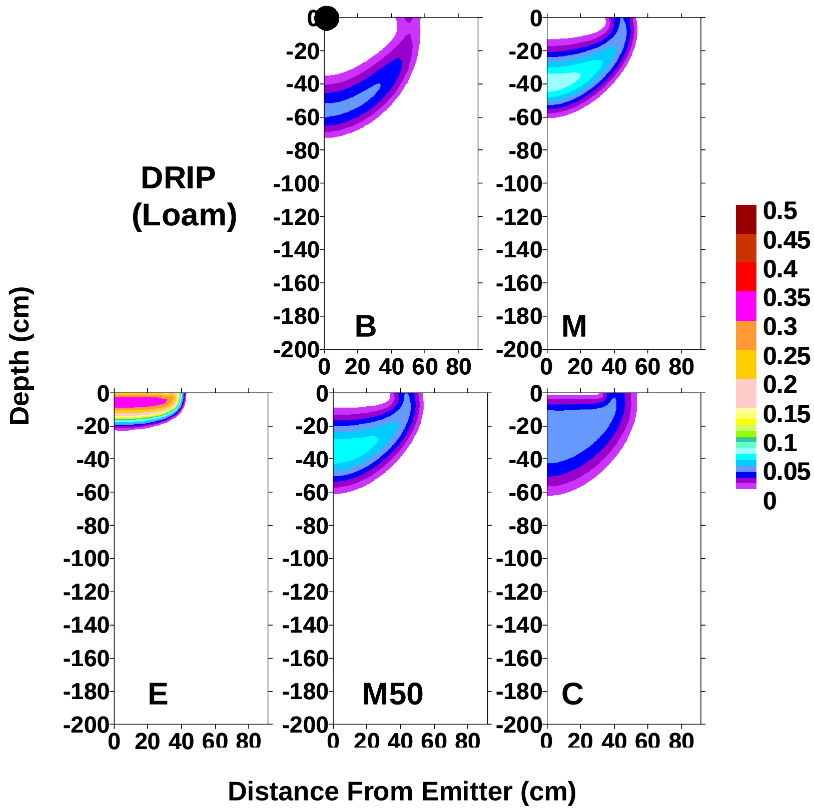

Figure 1. Nitrate distributions around the drip line for DRIP (Loam) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.

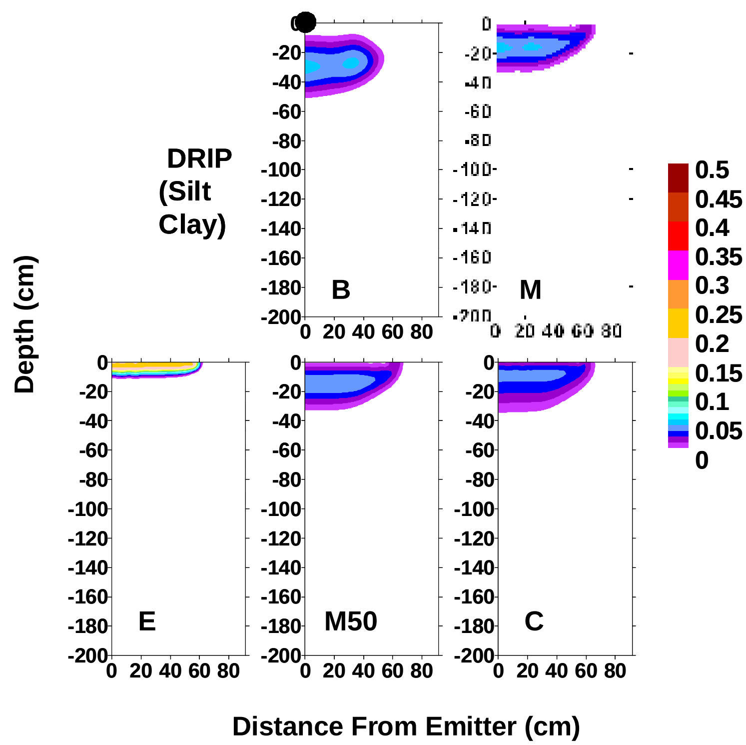

Figure 2. Nitrate distributions around the drip line for DRIP (Silt Clay) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.

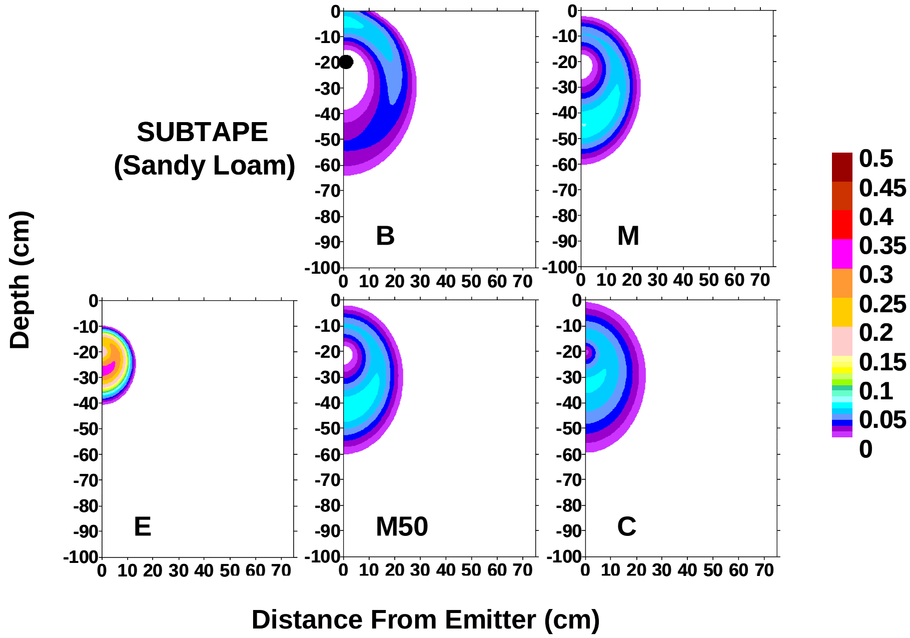

Figure 3. Nitrate distributions around the drip line for SUBTAPE (Sandy Loam) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.

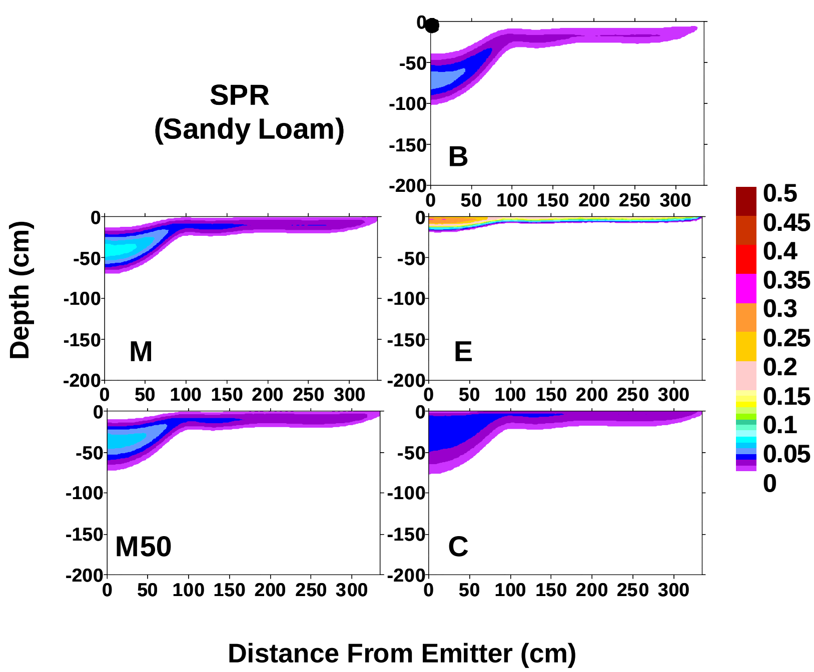

Figure 4. Nitrate distributions around the drip line for SPR (Sandy Loam) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.