Fertigation with Drip Irrigation for Maximum Availability and Minimum Leaching of Nitrate

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Introduction

Fertigation is the process of applying fertilizers through the irrigation water. For microirrigation systems, a recommendation frequently used for fertigation 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. The primary motivation for this practice is convenience.

Short-term fertigation events could result in relatively nonuniform distributions of fertilizer in the root zone and an increased potential for fertilizer leaching depending on the fertigation strategy. The objective of this study was to determine the effect of different fertigation strategies for microirrigation systems on water and nutrient use efficiencies and on nitrate leaching.

Materials and Methods

The HYDRUS-2D computer simulation model was used to assess the effect of different fertigation strategies on water and nutrient use efficiencies and on nitrate leaching. Outputs of the model include distributions of nitrate and soil water and a mass balance of nitrate in different parts of the root zone.

Phase I of the project evaluated the effect of different fertigation scenarios on the nitrate distribution in the soil and on nitrate leaching using a nitrate only fertilizer. A 28 d simulation period was used for the fertigation scenarios which were:

- microirrigation systems: microsprinkler (citrus) using a sprinkler discharge rate of 5 gal/h (SPR); surface drip irrigation (grapes) using 1 gal/h emitters (DRIP); surface drip irrigation (strawberries) using drip tape with a tape discharge rate of 0.45 gpm/100 ft (SURTAPE); subsurface drip irrigation (tomatoes) using drip tape buried at 8 inches with a tape discharge rate of 0.22 gpm/100 ft (SUBTAPE)

• 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: inject for 2 hours starting one hour after start of irrigation (B); inject for 2 hours in the middle of the irrigation set (M); inject for 2 hours starting 3 hours before cutoff of irrigation water (E); inject during the middle 50% of the irrigation set time (M50); inject continuously during the irrigation set (C).

Phase II evaluated the effect of fertigation strategies on the distribution and leaching of ammonium, urea, and nitrate for subsurface drip irrigation (SUBTAPE) and surface drip irrigation (DRIP) in loam. Fertilizer concentrations simulated the different forms of nitrogen found in UAN 32, an urea-ammonium nitrate (32-0-0) fertilizer solution commonly used for microirrigation. Reaction parameters used in the model were: hydrolysis – 0.38/d, nitrification rate – 0.2/d, and partition coefficient (K_d) for ammonium – 3.5 L/kg.

RESULTS AND CONCLUSIONS

Phase I - Nitrate

Nitrate is a highly mobile ion that moves readily with water. Thus, nitrate distributions around drip lines will be strongly affected by a particular fertigation strategy. The nitrate distributions shown in Figures 1 thru 5 occurred at the end of the first irrigation event after the start of fertigation.

Subsurface Drip Irrigation (SUBTAPE)

● Injecting for 2 h starting 1 h after the start of irrigation cycle resulted in a band of nitrate near the periphery of the wetted pattern at the end of the irrigation for in sandy loam with little or no nitrate near the drip line (shown by the white color) (Fig. 1A). The irrigation time was 27 h. Higher nitrate concentrations occurred above the drip line compared to below the drip line, the result of water flowing upward into dry soil above the drip line. Similar distributions occurred for loam and silty loam soil.

● Injecting for 2 h near the end of the irrigation accumulated nitrate in the immediate vicinity of the subsurface drip line as indicated by the red color near the drip line (Fig. 1B). Higher nitrate concentrations occurred in the soil compared to injecting near the beginning of the irrigation cycle strategy. Similar distributions occurred for loam and silty loam soil.

● Injecting during the middle 50% of the irrigation cycle spread the nitrate throughout most of the wetted area (Fig. 1C). Higher nitrate concentrations occurred below the drip line compared to above the line. This behavior is the result of a wetter soil above the drip line at the start of injection than occurred at the beginning of the irrigation, which reduced the upward flow of water for this strategy. Similar distributions occurred for loam and silty loam soil.

Surface Drip Irrigation (DRIP)

● Injecting for 2 h near the beginning of the irrigation resulted in band of nitrate starting about 15 to 18 inches from the drip line and extending to the periphery of the wetted pattern for a 2 h injection in loam (Fig. 2A). Leaching of nitrate occurred near the drip line (white color). The irrigation time was 1.5 days. Similar behavior occurred in sandy loam.

● Injecting for 2 h near the end of the irrigation resulted in a zone of relatively high nitrate concentrations next to the drip line (Fig. 2B). Similar behavior occurred in sandy loam.

● Injection during the middle 50% of the irrigation cycle caused a more uniform nitrate distribution throughout the soil profile compared to the other injection times (Fig. 2C). Similar behavior occurred in sandy loam.

● In silt loam, a horizontal band of nitrate extending nearly 20 inches from the drip line occurred with depth for a 2 h injection time near the beginning of the irrigation (data not shown). Ponded water on the soil surface flowing downward caused this behavior. Ponded water occurred because of the small infiltration rate of the soil compared to sandy loam and loam soil. Injecting near the end of the irrigation caused nitrate to accumulate near the surface in a horizontal band extending about 2 ft from the drip line. Injecting during the middle 50% of the irrigation distributed nitrate more evenly with depth.

Microsprinkler Irrigation (SPR)

● Nitrate patterns for a microsprinkler irrigation system reflected the water application pattern of the microsprinkler (data not shown). Most of the water applied by this sprinkler occurred within four feet of the sprinkler. Injecting for 2 h near the beginning of the irrigation for a short time period moved the nitrate down to depths between 18 and 40 inches near the sprinkler. Beyond 40 inches, nitrate remained near the soil surface.

● Injecting for 2 h near the end of the irrigation left most of the nitrate near the soil surface.

● Injecting during the middle 50% of the irrigation distributed the nitrate more evenly throughout the soil for distances smaller than 40 inches from the drip line compared to the other injection strategies.

Surface Drip Irrigation (SURTAPE)

The previous contour plots showed nitrate distributions for long irrigation times. However, for a short irrigation time of 3.2 h, little differences were found in the nitrate distributions for the various fertigation scenarios (data not shown).

Phase II

Urea is a highly mobile molecule that moves readily with water flowing through the soil. Urea is transformed to ammonium by hydroloysis. Ammonium is adsorbed to soil particles and does not move readily with water flowing through the soil. Ammonium is transformed to nitrate through a process called nitrification.

Results of the HYDRUS-2D modeling of urea, ammonium, and nitrate movement are illustrated by the data of SUBTAPE (loam) with 2 h fertigations occurring near the beginning of irrigation. Urea was distributed around the periphery of the wetted area with little urea immediately adjacent to the drip line prior to the start of the second fertigation event (3.54 d) (Fig. 3). After the end of the second fertigation (3.625 d), urea was highly concentrated in the immediate vicinity of the drip line, but at the end of the second irrigation (4.65 d), most of the urea was distributed near the periphery of the wetted area due to continuing the irrigation for a relatively long time period after injection ceased. Little urea remained in the immediate vicinity of the drip line. At the start of the third irrigation (7.00 d), the urea concentration had decreased substantially compared to that of 4.65 d due to hydrolysis. The urea distribution at the end of the 28 d simulation period (data not shown) was similar to that of 7.00 d.

Little movement of ammonium occurred between irrigations due to its adsorption characteristics (Fig. 3). At the end of the second fertigation event, relatively high concentrations occurred immediately adjacent to the drip line, but those concentrations decreased by the end of the second irrigation. Little change in the ammonium distribution occurred during the 28 d simulation period.

At the beginning of the second fertigation event, nitrate was distributed relatively uniformity around the drip line until near the edge of the wetted area (Fig. 3). At the end of the second fertigation event (3.625 d), nitrate was highly concentrated immediately adjacent to the drip line. However, at the end of the second irrigation (4.65 d), the nitrate concentration near the drip line decreased substantially due to leaching during the remainder of the irrigation, while nitrate concentrations further away from the drip line increased with higher nitrate concentrations above the drip line than below. At the beginning of the third irrigation (7.00 d), nitrate concentrations had increased throughout much of the wetted area compared to that at the end of the second irrigation (including near the drip line) due to hydrolysis of urea and nitrification of ammonium. Nitrate continued to accumulate in the soil profile during the 28 day simulation period.

Conclusions

For surface drip irrigation systems, short fertigation events at the beginning of irrigation followed by a long irrigation time resulted in nitrate accumulating in the periphery of the wetted pattern, beyond the area of maximum root density and in more leaching of nitrate compared to short fertigation events near the end of the irrigation cycle. The nitrate distribution in the soil was more uniform for fertigations during the middle 50% of the irrigation cycle compared to short fertigation events. Nitrate leaching was highest for short fertigations near the beginning of irrigation, while leaching was smallest for fertigations near the end of the irrigation.

For subsurface drip irrigation, no conclusions could be made about the effect of a fertigation strategy on nitrate leaching because of upward flow of water above the drip line. This flow resulted in more nitrate accumulation above the drip line for short fertigation events at the beginning of irrigation compared to the other strategies. Nitrate accumulation above the drip line was the smallest for short fertigation events at the end of the irrigation cycle because little upward flow occurred due to the wet soil at the time of fertigation.

Similar nitrate distributions occurred for short irrigation events, regardless of the fertigation strategy.

Urea readily moved with water during irrigation, but because of hydrolysis, urea did not accumulate in the soil with time. Little ammonium movement occurred throughout the wetted area, and little ammonium accumulation occurred with time due to nitrification. Nitrate continued to accumulate below the drip line during the simulation period. Nitrate leaching was slightly smaller for the UAN 32 fertilizer compared to the nitrate only fertilizer used in Phase I.

References

Hanson, B.R., J.W. Hopmans, A. Gardenas, and J. Simunek. 2004. Crop Nitrate Availability and Nitrate Leaching under Microirrigation for Different Fertigation Strategies. Progress Report, May 20, 2004, submitted to the California Department of Food and Agriculture Fertilizer Research and Education Program.

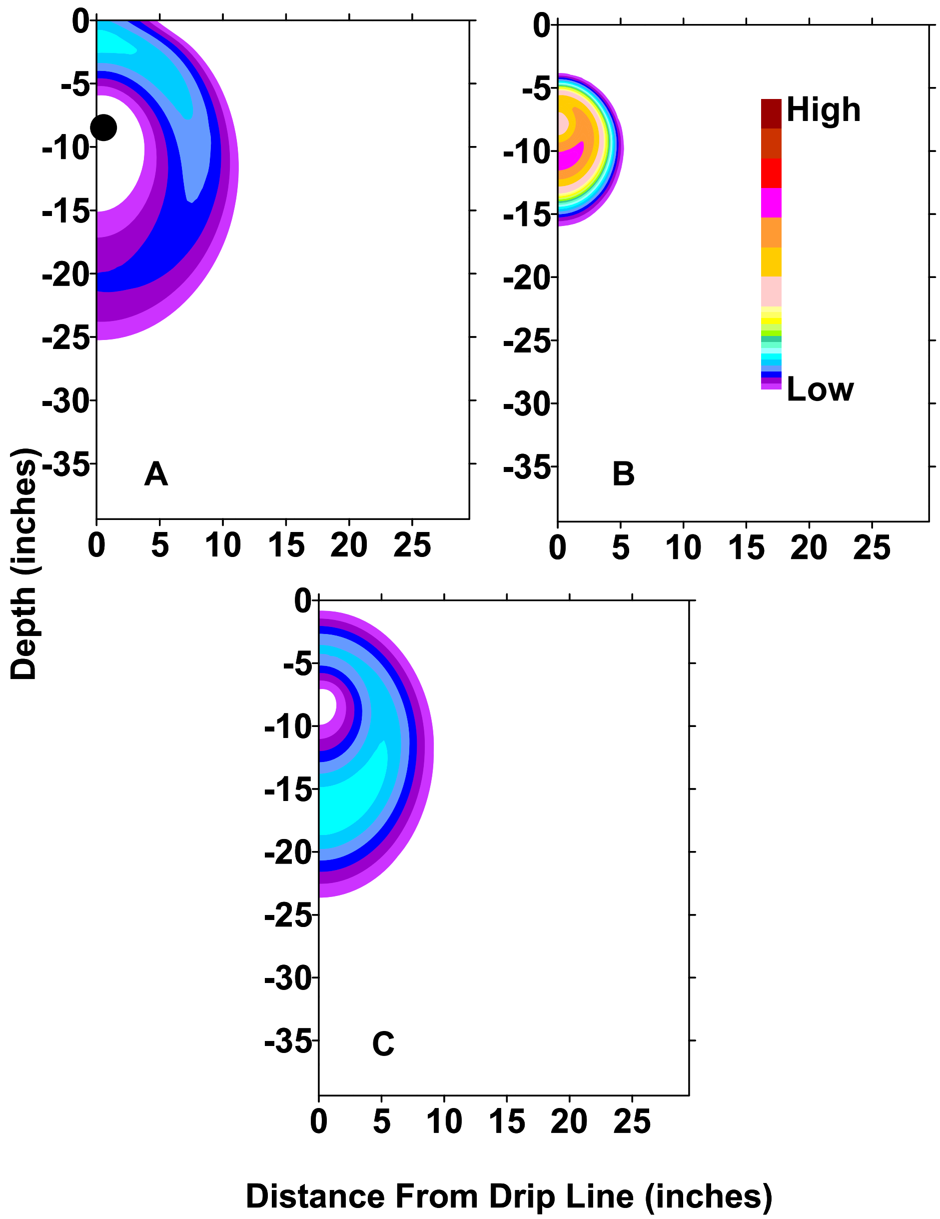

Figure 1. Nitrate distributions around the drip line at the end of the first fertigation event of a subsurface drip system in sandy loam for A) nitrate injection for 2 hr at the beginning of the irrigation starting 1 h after start of irrigation, B) injection for 2 h ending 1h before the end of the irrigation, and C) injection during the middle 50 percent of the irrigation set. Duration of irrigation was 27 h. The black dot is the location of the drip line. The color bar shows relative concentrations.

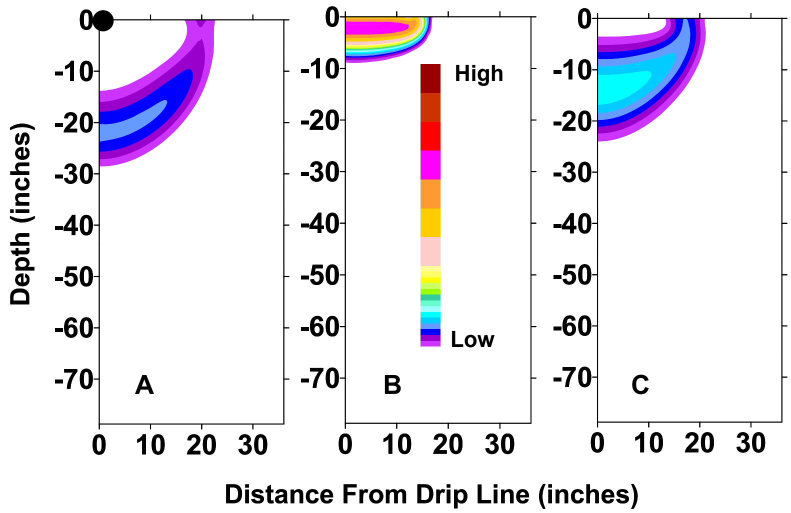

Figure 2. Nitrate distributions around the drip line of a surface drip system in loam soil at the end of the first fertigation event for A) nitrate injection for 2 hr at the beginning of the irrigation starting 1 h after start of irrigation, B) injection for 2 h ending 1h before the end of the irrigation, and C) injection during the middle 50 percent of the irrigation set. Duration of irrigation was 36 h. The black dot is the location of the drip line. The color bar shows relative concentrations.

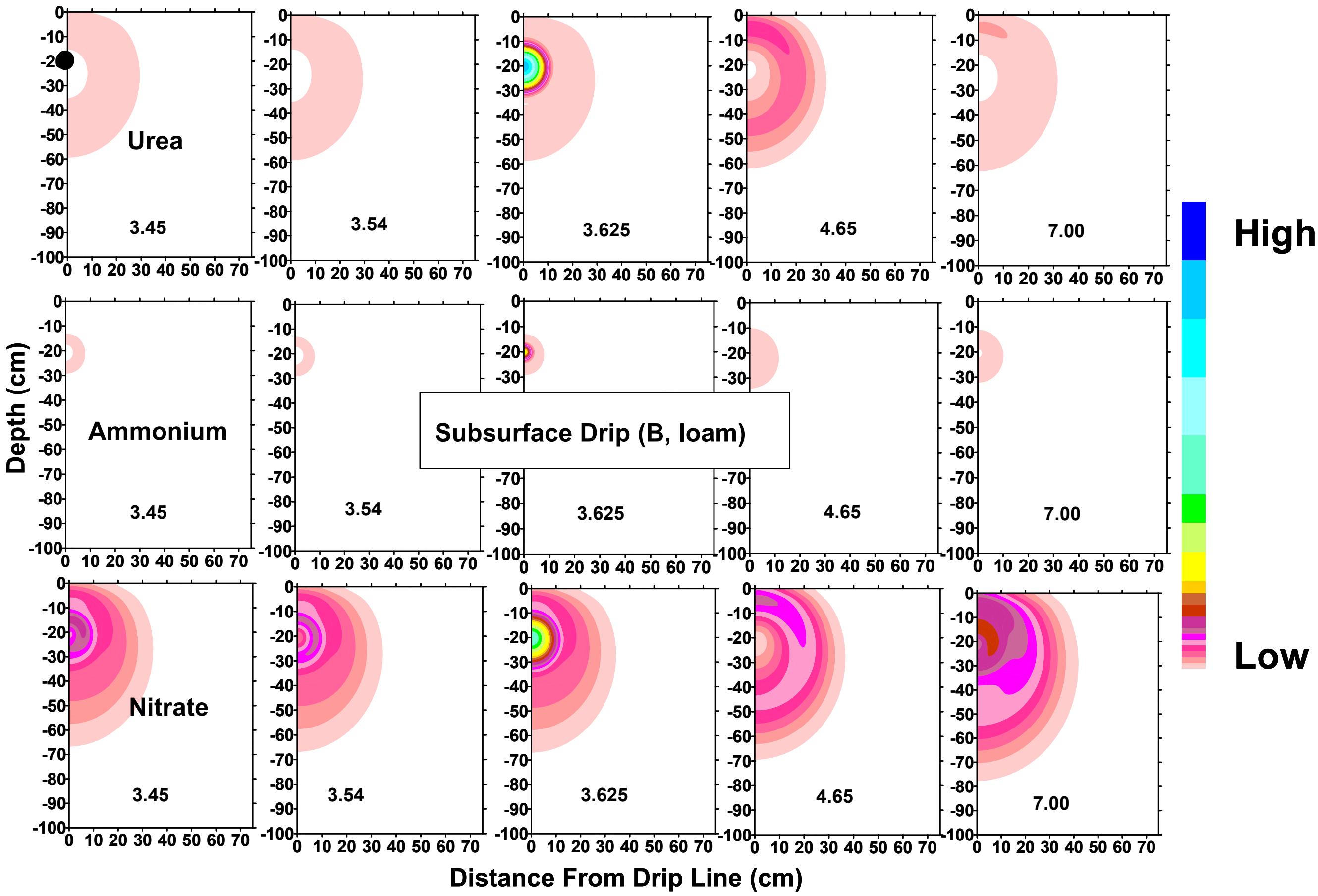

Figure 3. Distributions of urea, ammonium, and nitrate during the second fertigation event for the subsurface drip irrigation. Fertigation occurred for 2 h starting 1 h after the start of irrigation. Numbers are the days after start of the fertigation simulations: 3.45 - start of second irrigation; 3.54 - start of second fertigation; 3.625 - end of second fertigation; 4.65 - end of second irrigation; 7.00 - start of third irrigation.