HS1008

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IFAS Extension

On-Farm Demonstration of Soil Water Movement in Vegetables Grown with Plasticulture[1]

E.H. Simonne, D.W. Studstill, R.C. Hochmuth, J.T. Jones and C.W. Starling[2]

Irrigation management is directly linked not only to yield and economical value of vegetable crops, but also to the long-term sustainability and environmental impact of vegetable production. Precise knowledge of where irrigation water goes has direct implications on irrigation management, fumigant application (Hochmuth et al., 2002; Santos et al., 2003) and fertilizer leaching (Simonne et al., 2002). The recommendations of UF/IFAS for irrigation management for vegetable crops include using a combination of target irrigation volume, a measure of soil moisture to adjust this volume based on crop age and weather conditions, a knowledge of how much water the root zone can hold, and an assessment of how rainfall contributes to replenishing soil moisture (Simonne et al., 2003). Improving irrigation management in vegetable crops has been limited by the fact that water movement in soil is a process that cannot be easily seen because it occurs under ground.

A direct knowledge of how much water can be stored in the root zone can be gained by visualizing water movement in the soil using soluble dye (German-Heins and Flury, 2000). A blue dye and controlled irrigation conditions were used to visualize the wetting pattern of drip irrigation using different drip tapes on sandy soils representative of vegetable producing areas of Florida (Santos et al., 2003; Simonne et al., 2003, 2004). As research tools, these dye tests were used for the following purposes:

- describe the shape of the wetted zone for several water volumes applied by drip irrigation,
- determine height, width, and depth of the wetted zone,
- and determine if soluble fertilizer and the water front represented by the dye move together in the soil (Simonne et al., 2004).

As educational tools, these dye tests have been used to show growers how deeply water penetrates into several soils and how drip tape flow rate and emitter spacing affects wetted zones. While novel in their approach, these dye tests have used single irrigation events and were done without an actively growing vegetable crop.

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Past educational efforts and fertilization recommendations have generally attempted to reduce environmental impact by reducing fertilizer application rates. While this approach may be valid, it is not practical since fertilizer costs only represent 10% to 15% of the overall preharvest production costs. Fertilizer is often applied at rates above the crop nutritional requirement as a means to decrease the risk of reduced yields due to shortage of fertilizer, especially close to harvest. It is possible to follow a different approach for improving fertilizer management. As water is the vehicle for soluble nutrient movement in the soil, it may be possible to improve nutrient management by improving irrigation management. If irrigation water stays in the root zone, smaller amounts of fertilizer are likely to be leached. If growers are shown how their current irrigation schedules affect water movement in their fields, they are more likely to understand how water and nutrients are linked. With this integrated approach, sustainability becomes compatible with economical profitability.

The goals of this project were to demonstrate to cooperating growers how irrigation and fertilizer management are linked together and how management may prevent water movement below the root zone. More specifically, the objectives were to:

1. establish partnerships with three key growers and discuss fertilizer and irrigation management,
2. determine the position of the water front throughout the growing season,
3. diagnose crop nutritional status, and
4. determine nitrate distribution in the soil profile at the end of the growing season.

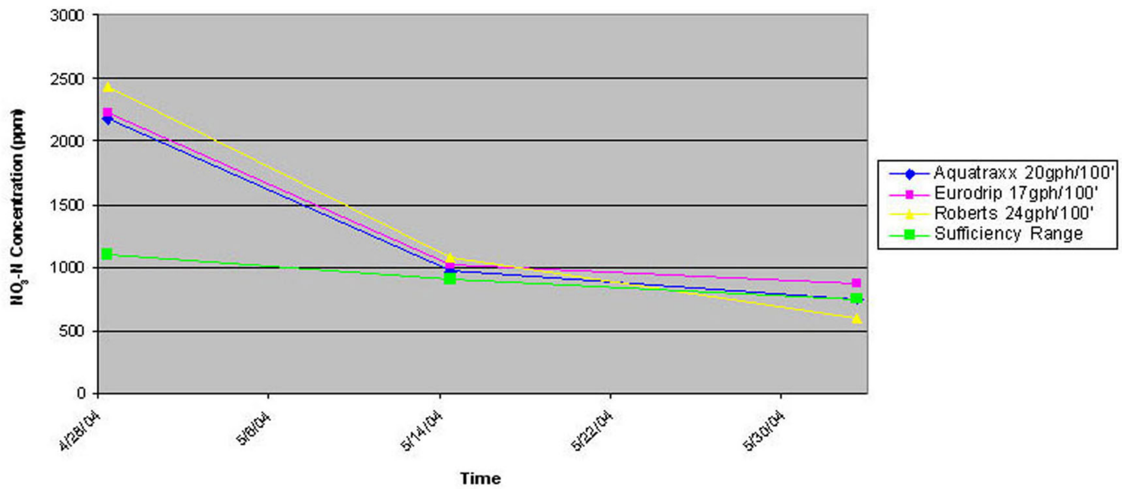
From a producer's stand point, this information will be used to increase sustainability by reducing water used and environmental impact of vegetable production. From a regulatory stand point, this information will contribute to demonstrate the efficacy of possible nutrient/water Best Management Practices and set practical management expectations.

Methodology

The project was conducted in North Florida in the spring of 2004 on three commercial vegetable fields (referred to as site 1-cantaloupe, site 2-watermelon, and site 3-cantaloupe) with three cooperating growers who had participated in previous UF/IFAS irrigation management projects (Simonne et al., 2001). These growers are recognized as leaders in water and nutrient management. The approach was similar at the three sites. Growers prepared the field with raised beds, drip tape, and plastic mulch. Sections of beds were replaced with drip tape with three different flow rates (Table 1). Other cultural practices were conducted by the cooperating grower throughout the growing season (Table 2). Soluble blue dye (Terramark SPI High Concentrate, ProSource One, Memphis, TN) was injected three times at each site and was traced through three or four digs (Table 3). Petiole NO_3-N and K concentrations were also determined throughout the crop (Table 3) and compared to published sufficiency ranges (Maynard et al., 2003). Soil samples were taken in one-foot increments up to the 6 foot depth at each location after final harvest. Soil samples were dried, sieved to pass a 2-mm screen, and sent to the University of Florida Analytical Research laboratory for NO_3-N and NH_4-N analysis using methods 352.3 and 350.1, respectively (US EPA, 1983a,b).

Findings, Results and Discussion

Spring 2004 was warm and dry in North Florida; rainfall marginally contributed to replenishing soil moisture and did not interfere with the irrigation schedules. Cooperating growers were eager to participate in this project and showed continuous interest and support. Their respective fertilizer and irrigation schedules were considered to be sophisticated because they took full advantage of the flexibility of drip irrigation to split fertilizer applications and to change irrigation schedules based on plant growth. Yet, each grower had his own approach to fertilizer management, as the ratio of preplant:injected and the starting date of injection varied widely. These different approaches were consistent with current UF/IFAS fertilizer recommendations. Nitrate-nitrogen and K concentrations in petioles were all at or above the



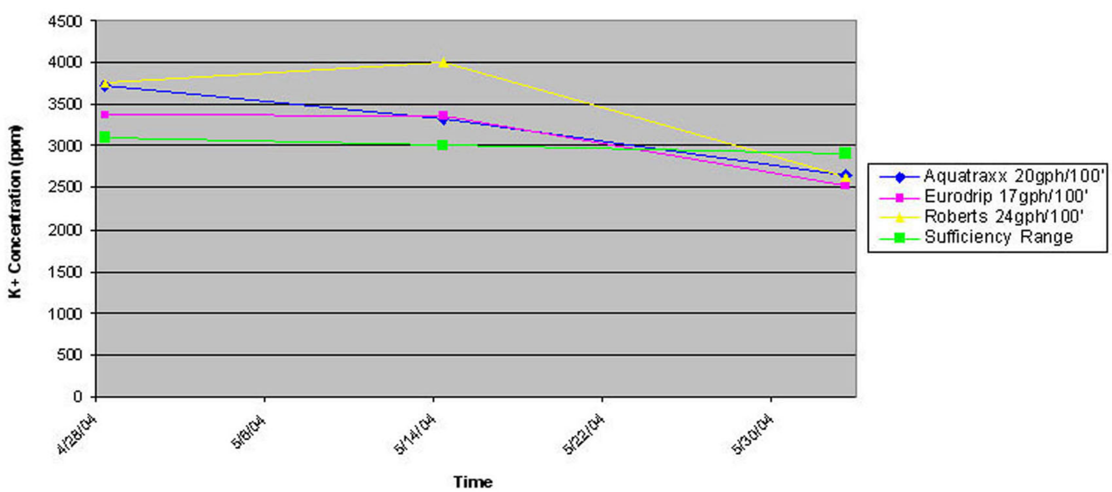
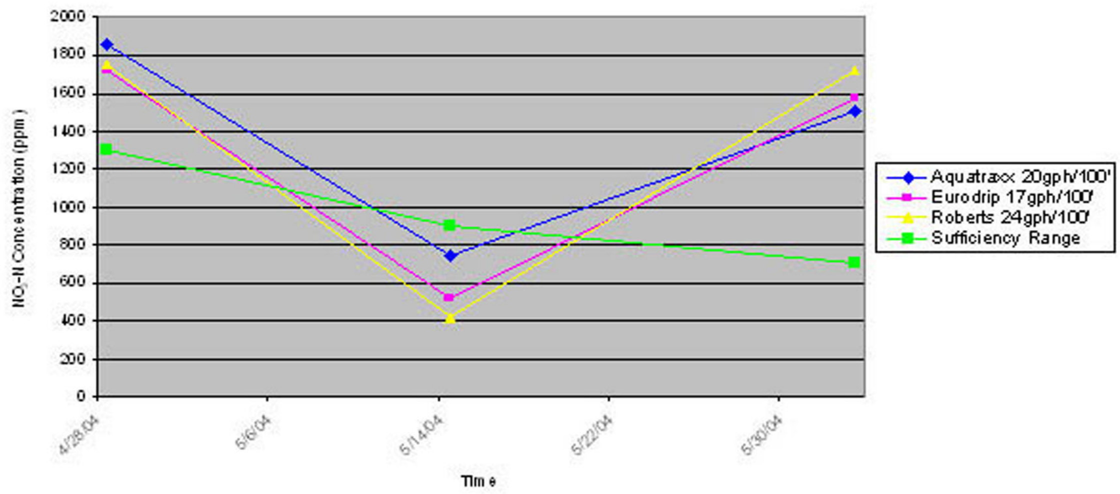


Figure 1. Nitrate and potassium concentrations (mg/L) in sap petioles of cantaloupe (site 1).

sufficiency ranges (Figs. 1, 2, 3). Drip-tape flow rate had no practical influence on crop nutritional status. As drip irrigation flow rates ranged from 59% to 100% of all cooperating growers' rates, this suggests that crop nutritional status could be maintained while reducing fertigation inputs.

Soil types were different at the three sites. Soils were sandy at the 1-cantaloupe and 2-watermelon sites, and relatively heavier (loamy) at the site 3-cantaloupe. Hence, the positions of the water front as represented by the dye were also different and are discussed separately (Table 4). At the 1-cantaloupe site, the depth of the first dye ring ranged between 30 and 38 inches and averaged 34 inches on April 28. From transplanting to that date, irrigation applied was for transplant establishment and was only 50 min/day (Table 2). Yet, 34 inches is well below the root zone. On the next dig two weeks later (May 14), the dye injected on April 6 (1st dye) had moved only an average of 5 inches deeper. On May 14, the dye injected on April 28 (2nd dye) had a depth ranging between 16 and 23 inches, with a 19-inch average. The second dye had moved less than the first dye. This is most likely due to differences in cantaloupe water use. Small plants (between April 6 and 14) used less water than larger plants (between April 28 and May 14). This example confirms the prediction



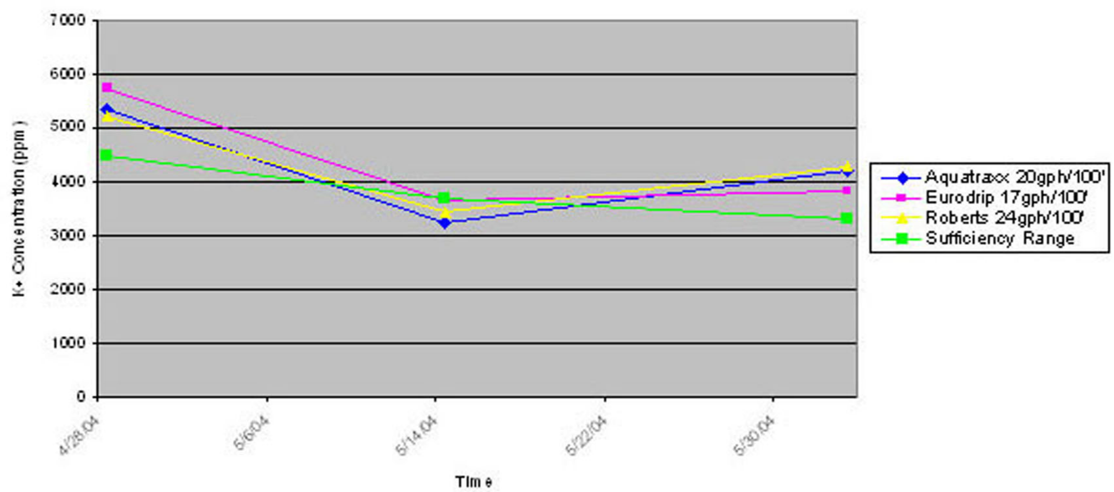


Figure 2. Nitrate and potassium concentrations (mg/L) in sap petioles of watermelon (site 2).

that irrigation water needed early in the season for plant establishment may push the water front well below the root zone. Changing the existing irrigation schedule from 1 x 50 min/day to 2 x 30 min/day may not be currently practical as it takes approximately 15 minutes to charge the drip irrigation system. If this 2 x 30 min/day schedule were adopted with the current irrigation system, a large (approximately 50%) portion of the irrigation cycle would be used for system charge, which is likely to decrease uniformity of application.

A costly possibility to reduce the charging time would be to modify the drip irrigation system to keep it continuously pressurized. If this is not economically feasible, two alternative practices may be used to reduce the risk of nutrient leaching. First, it would be possible to modify the fertilizer program to include a smaller amount of preplant nitrogen and increase proportionally that injected after plant establishment. While this approach is theoretically valid, the feasibility of a 100% injected fertilizer program needs to be demonstrated first before growers are likely to adopt it. The second alternative is to change water distribution in the bed by using two drip tapes, each with lower nominal flow rates. For example, if the existing 24 gal/100ft/hr drip tape is replaced by two 16 gal/100ft/hr drip tapes, the same amount of water may be applied by reducing irrigation time by 25%. Using two drip tapes would reduce approximately half the vertical movement of water but would slightly increase production cost. However, the cost of the additional drip tape could be covered through cost-sharing.

effect of drip tape flow rate was detectable only between digs 2 and 3. Reducing drip tape flow rate by 33% (from 24 to 16 gal/100ft/hr), reduced the position of the water front on the date of dig 3 by approximately 50% (28 vs. 14 inches). Cantaloupe roots were found mainly in the plough zone (top 12 inches) but several actively growing roots were found in the top 42 inches. These results suggest that reducing irrigation amount by 25% (by using a drip tape with reduced flow rate) may help in keeping the

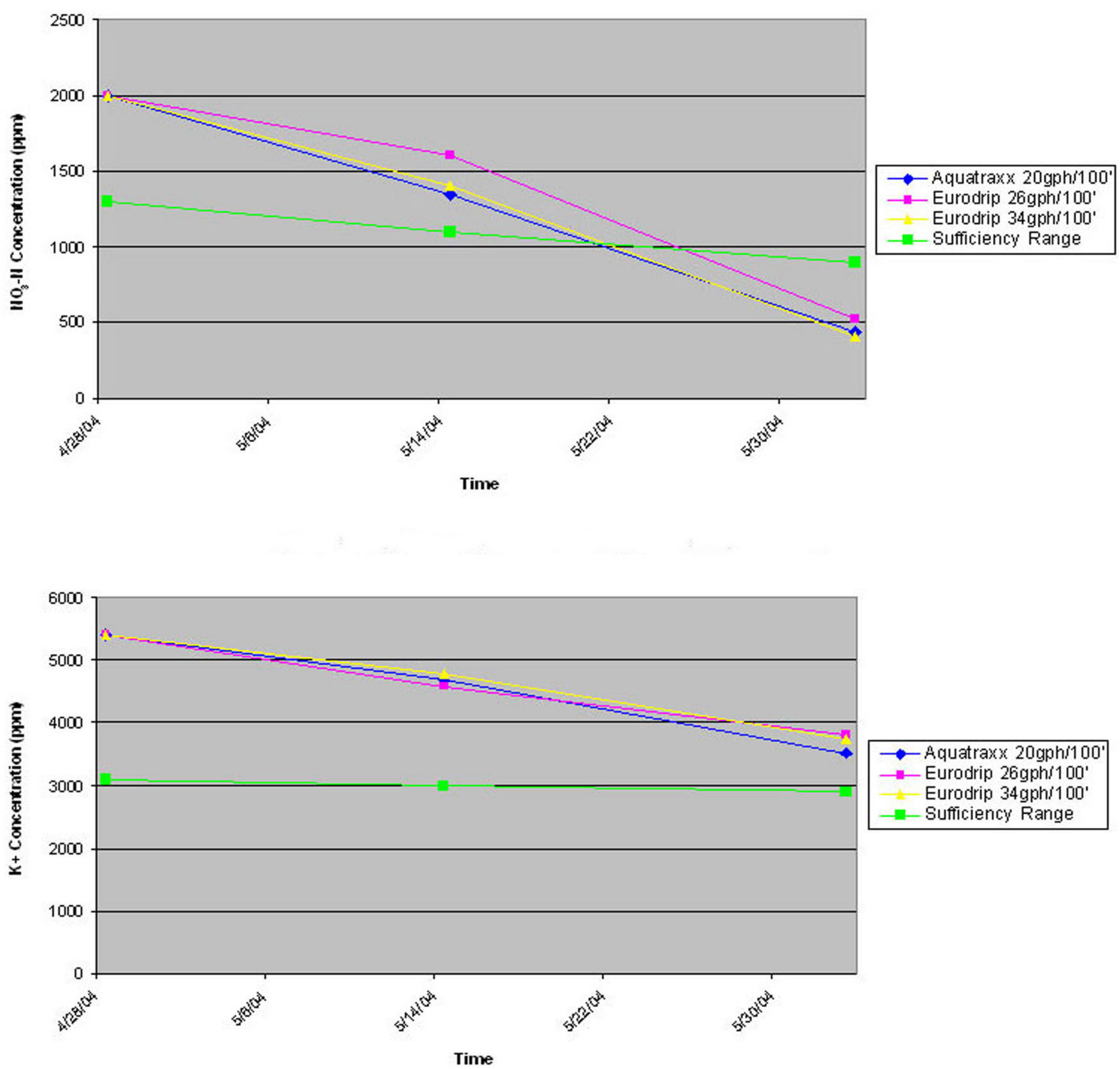


Figure 3. Nitrate and potassium concentrations (mg/L) in sap petioles of cantaloupe (site 3).

On June 2, the position of the third dye (injected on May 14) ranged between 14 and 28 inches and averaged 22 inches. Although irrigation was at that time several hours daily, large cantaloupe plants that were setting fruits used a large amount of water. The wetted zone within the root zone. Therefore, these findings and observations together suggest that it may be possible to keep the wetted zone within the root zone of cantaloupes on this sandy soil by using two drip tapes and reducing current grower's schedule by 25%.

At the 2-watermelon site, the depth of the first dye ring (injected on April 6 and dug on April 28) ranged between 12 and 24 inches and averaged 20 inches. At this site, the depth of the dye ring tended to decrease as drip tape flow rate decreased. These results suggest that water used for watermelon establishment may be reduced by approximately 20%. A valve malfunction shortly after April 28 resulted in a non-scheduled 6-hour irrigation event that pushed the water front below the 45-inch depth on May 14. The depth of the third dye ring (injected on May 2) and dug on June 2 ranged between 11 and 19 inches and averaged 15 inches. These results show that the grower's schedule during fruit set and enlargement was adequate and did not result in a dye front moving deep below the root zone. Lessons from the 2-watermelon site are similar to those from the 1-cantaloupe site. In the absence of rain, the risk of the water front moving below the root zone is greatest during crop establishment and when plants are small 1 to 5 Weeks After Transplanting [WAT]).

At the 3-cantaloupe site, the depth of the first dye ring (injected on April 6, dug on April 28) ranged between 16 and 18 inches. While roots may be found at the 18-inch depth when cantaloupe plants are fully grown, this depth was below the root depth when the plants were at the 6-inch long vine stage. On May 14, the dye injected on April 6 could not be found, and the depth of that injected on April 28 ranged between 22 and 38 inches, and averaged 30 inches. On June 2, the depth of the dye injected on May 14 ranged between 17 and 20 inches, and averaged 18 inches. On June 30, the depth of the dye injected on May 14 was similar to that found on June 2: it ranged between 17 and 20 inches, and averaged 18 inches. Because of the heavier soil texture, water tended to move less at this site than at the two other sites. However, it was also observed at this site that the greatest dye movement occurred when the plants were small. The grower's schedule, when the plants were fully grown, seemed adequate.

Nitrate and ammonium concentrations in the soil significantly varied by depth (Table 5). At the 1-cantaloupe site, all NO_3-N concentrations were below 1 mg/kg, and were significantly lower at the 48-60 inch depth. Ammonium concentration was not affected by depth and averaged 5.10 mg/kg NH_4-N between the 0 and 60-inch depth (Fig. 4). At the 2-watermelon site, NO_3-N concentration was significantly greater at the 24-26 inch depth, while NH_4-N concentration was significantly greater in the 0-12 inch zone. The hard pan at the 3-cantaloupe site limited the depth of soil sampling to 48 inches. Nitrate-nitrogen concentration was significantly higher in the 12 inches above the hard pan (36-48 inch depth) than in the 0- to 36-inch section, while NH_4-N concentration was higher in the 0- to12-inch depth. These results show that distribution of nitrate and ammonium are different in different types of soil. In a deep sandy soil, NO_3-N may move vertically rapidly, while it may accumulate above an impermeable layer, and possibly move laterally thereafter. The effect of drip tape flow rate on the distribution of NO_3-N and NH_4-N in the soil profile was not significant at all three sites.

Conclusions

The irrigation and fertilizer schedules used by cooperating growers followed UF/IFAS splitting and scheduling recommendations and represented proposed nutrient BMPs well. It was not possible to observe the three dye rings simultaneously at the end of the experiment, showing that these near-optimal fertigation schedules did not keep the water front within the root zone for the entire season. At the three sites, greatest water movement was observed at the beginning of the growing season between 1 and 5 WAT. This period should be the focus of educational efforts. Cooperating growers' irrigation schedules were overall adequate for the remainder of the season but could be reduced by 20%. Using tapes with flow rates ranging from 59% to 100% did not practically affect crop nutritional status and water movement. Cooperating growers' fertigation schedules maintain crop nutritional status within the recommended range.

As observed in previous dye tests, the uniformity of water distribution in the soil profile decreased with depth as water found paths of preferential flow. Hence, leaching may not be uniform in a field even when the uniformity of the drip system exceeds 90%.

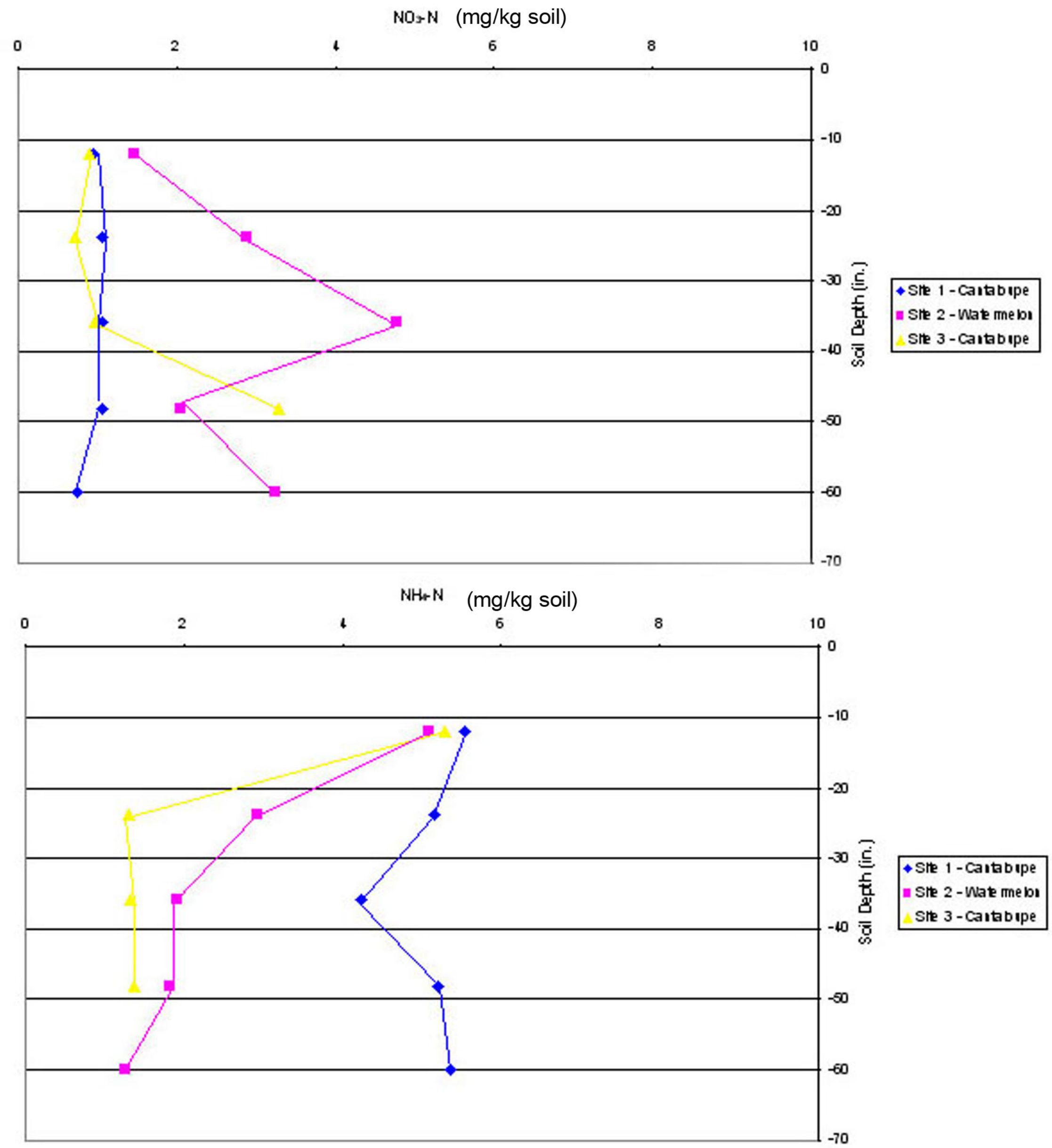


Figure 4. Soil nitrate (NO_3-N) and ammonium (NH_4-H) concentrations in soils (mg/kg) in three commercial vegetable fields after harvest between the 0- and 60-inch depths.

Consequently, no consistent practical benefit was found in reducing irrigation rates as an attempt to reduce leaching. However, theoretically, reducing irrigation rates should reduce leaching. Another consequence of field heterogeneity is that growers tend to irrigate based on the dry spots. This often results in increasing irrigation on the other parts of the field.

This project has demonstrated again the importance of soil texture in water movement. Water moved vertically faster on sandy soils than on the loamy soil. Lateral water movement was also less on the sandy soil than on the loamy soil. This project is a good illustration of the fact that the demonstration and implementation of BMPs are possible when vegetable growers are actively involved.

Summary

The long-term sustainability of commercial vegetable production requires increased fertilizer and irrigation efficiency. Three vegetable growers recognized as leaders in fertilizer and irrigation management in North Florida were selected to demonstrate how irrigation and fertilizer management are linked together and how management may prevent water movement below the root zone of two muskmelon (cantaloupe) fields and one watermelon field, all grown with plasticulture. The approach was to create irrigation rates by using drip tapes with different flow rates, inject colored dye in the irrigation water three times during the growing season, and dig the soil profile to determine the depth of the dye. Similar results were found at all three locations; water movement was greater early in the season (1 to 5 weeks after establishment) and the dye moved below the root zone (20 to 30 inches deep). The vertical movement of the dye was less on a loamy soil with an impermeable layer than on the two deep sandy soils. The uniformity of water movement decreased as depth increased. Overall, these results show that some leaching is likely to occur on light-textured soils, even when UF/IFAS recommended practices are followed. Educational efforts should focus on fertigation management during the 2-3 weeks after crop establishment. Based on these observations, cooperators are considering improving their fertigation practices by using two drip tapes, reducing preplant fertilizer, using a 100% injected N/K program, and/or adding organic matter to the soil. This project shows that vegetable growers are more likely to try and adopt sustainable practices when they actively participate in the educational process than when production changes are mandated through legislation.

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Table 1. Drip tapes used during three on-farm dye tests in the spring of 2004 in North Florida.

Manufacturer	Flow Rate		Emitter Spacing (inch)
	Nominal (gal/100 ft/hr)	Relative to grower (%)	
Site 1-Cantaloupe			
Roberts	24	100	12
Aquatraxx	20	83	12
Eurodrip	16	67	12
Site 2-Watermelon			
Roberts	24	100	12
Aquatraxx	20	83	12
Eurodrip	16	67	12
Site 3-Cantaloupe			
Eurdrip-grower	34	100	12
Eurodrip	25	74	12
Aquatraxx	20	59	12

Table 2. Cultural practices used during three on-farm dye tests in 2004 in North Florida.

Cultural Practice	Site 1 - Cantaloupe	Site 2 - Watermelon	Site 3 - Cantaloupe
Location	North Florida	North Florida	North Florida
Soil Type	Blanton Fine Sand	Plummer Fine Sand	Orangeburg fine sandy loam
Crop	Muskmelon	Triploid watermelon	Muskmelon
Variety	Athena (transplanted)	Sugar Heart with 790 pollenizer (both transplanted)	Athena (seeded)
Crop stage of growth			
Planting date	March 25	March 23	April 1
April 6 (dye injection 1)	2 leaves	6-inch long vines	Few plants visible
April 28 (dye injection 2)	2-ft long vines; 1- inch fruit	2-ft wide vines; begin bloom	6-inch long vines
May 14 (dye injection 3)	Closed rows; 5-inch fruits	Closed rows; full-size fruits	1 to 2-ft long vines; early bloom
June 2	Harvest	Harvest	
June 30			Harvest
Irrigation schedule			
Early season	1-4 WT[z]: 50 min/day	1-3 WAT : 45 min/day	1-3 WAS - 3 x 30 min/day
Mid-season	5-6 WAT : 1 hr/day	4 WAT : 1 hr/day	as needed
Late season	7 WAT : 1.5 hr/day	5-6 WAT : 2 x 1 hr/day	as needed

Table 2. Cultural practices used during three on-farm dye tests in 2004 in North Florida.

	8 WAT to harvest : as needed	7 WAT to harvest : 3 x 1 hr/day	as needed
Preplant soil test	yes	yes	yes
Fertilizer schedule	Some preplant; weekly injection throughout the crop	Some preplant; injection start after fruit set	Some preplant; weekly injections throughout the crop
[z]WAT = weeks after transplanting; WAS = weeks after seeding			

Table 3. Schedule for petiole sampling, dye injection, digging, and soil sampling during three on-farm dye tets in 2004 in north Florida.

Event	Site 1-Cantaloupe	Site 2-Watermelon	Site 3-Cantaloupe
Petiole Sampling and Sap Testing			
Petiole 1	April 28	April 28	April 28
Petiole 2	May 14	May 14	May 14
Petiole 3	June 2	June 2	June 2
Dye Injection			
Dye 1	April 6	April 6	April 6
Dye 2	April 28	April 28	April 28
Dye 3	May 14	May 14	May 14
Digging			
Dig 1	April 28	April 28	April 28
Dig 2	May 14	May 14	May 14
Dig 3	June 2	June 2	June 2
Dig 4	June 30	June 30	June 30
Soil Sampling			
Soil Sample 1	July 1	June 30	June 30

Table 4. Depth of the blue dye (inch) representing the wetted zone on three commercial fields in north Florida in the spring of 2004.

Trt. No.	**Drip tape manufacturer (Flow rate relative to grower's rate)**	**Digging date**					
		April 28	**May 14**		**June 2**		
		Dye 1	**Dye 2**	**Dye 1**	**Dye 3**	**Dye 2**	**Dye 1`**
Site 1 - Cantaloupe							
1	Roberts (100%)	32	17	35	28	>50	>50
2	Aquatraxx (83%)	38	23	55	24	>50	>50
3	Eurodrip (67%)	33	16	30	14	>50	>50
	Average	34	19	40	22	>50	>50
Site 2 - Watermelon							

Table 4. Depth of the blue dye (inch) representing the wetted zone on three commercial fields in north Florida in the spring of 2004.

Trt. No.	Drip tape manufacturer (Flow rate relative to grower's rate)	Digging date					
		April 28	May 14		June 2		
		Dye 1	Dye 2	Dye 1	Dye 3	Dye 2	Dye 1`
1	Roberts (100%)	24	>45	>45	6	>45	>45
2	Aquatraxx (83%)	21	>45	>45	19	>45	>45
3	Eurodrip (67%)	12	>45	>45	11	>45	>45
	Average	20	>45	>45	15	>45	>45
Site 3 - Cantaloupe							
1	Eurodrip-G (100%)	--	22	>40	20	>30	>30
2	Aquatraxx (74%)	18	30	>40	17	>30	>30
3	Eurodrip-UF (59%)	--	38	>40	17	>30	>30
	Average	18	30	>40	18	>30	>30

Table 5. Soil nitrate (NO_3-N) and ammonium (NH_4-H) concentrations in soils (mg/kg) in three commercial vegetable fields between the 0 and 60-inch depths.

Depth (in)	Nitrate (mg/kg)	Ammonium (mg/kg)
Site 1 - Cantaloupe		
0-12	0.95 a	5.54 a
12-24	1.07 a	5.17 a
24-36	1.04 a	2.24 a
36-48	1.05 a	5.20 a
48-60	0.74 b	5.37 a
R^2	*0.91*	*0.44*
p-value	*0.02*	*0.89*
CV (%)	*17*	*27*
Site 2 - Watermelon		
0-12	1.47 b	5.09 a
12-24	2.89 b	2.92 b
24-36	4.78 a	1.91 b
36-48	2.05 b	1.83 b
48-60	3.25 ab	1.26 b
R^2	*0.66*	*0.74*
p-value	*0.01*	*0.01*
CV (%)	*48*	*51*
Site 3 - Cantaloupe		
0-12	0.90 b	5.31 a
12-24	0.72 b	1.30 b
24-36	0.97 b	1.32 b
36-48	3.27 a	1.37 b
48-60	--	--
R^2	0.90	*0.88*

Table 5. Soil nitrate (NO_3-N) and ammonium (NH_4-H) concentrations in soils (mg/kg) in three commercial vegetable fields between the 0 and 60-inch depths.

Depth (in)	Nitrate (mg/kg)	Ammonium (mg/kg)
p-value	*0.01*	*0.01*
CV(%)	*38*	*42*