Water and Nitrogen BMPs for Tomato and Watermelon: Water Quality and Economics[1]

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Introduction

Rapid movement of nitrogen from vegetable fields into Florida's shallow water table environments is a cause of concern for both production and environmental aspects. Excessive leaching from Florida's sandy soils combined with the short distance between the soil surface and ground water creates a challenge for vegetable growers to keep water and nutrients in the root zone within the plant sufficiency range. Water management involves controlling the water table depth for seepage irrigation, which is the most common irrigation method for vegetables in south and northeast Florida, to keep optimal soil moisture in the root zone. A major component of nutrient management is applying fertilizer at recommended fertilizer rates.

Growers apply both water and N fertilizer to maximize fruit production. However, applying fertilizer rates beyond crop needs can result in excessive nutrient. This practice is a cause for concern for Florida's water resources because N is mobile in the environment, and is associated with negative impacts on ecosystems caused by eutrophication. To help mitigate the water quality impacts of vegetable production, state agencies in coordination with producers and UF/IFAS have developed water and fertilizer best management practices (BMPs). The vegetable industry, however, has often questioned the efficacy of these BMPs and questioned whether these BMPs can be implemented without reducing yields.

BMP Study

A field study was designed to evaluate the effect of nutrient and water BMPs on crop yield and N leached from vegetable fields in south Florida. The study was conducted on a research farm located at the UF/IFAS Southwest Florida Research and Education Center in Immokalee. The study evaluated two production systems composed of two levels of water and nutrient inputs for tomato and watermelon production with seepage irrigation (Figure 1). The average water and N fertilizer rates used by growers (grower-average) in south Florida were compared with the recommended BMP rates (Table 1). Tomatoes were produced for four seasons (spring and fall) (Table 1), while watermelon was produced for two seasons (spring only). The grower-average N rates for tomato (373 lb./ac.) and watermelon (265 lb./ac.) were determined from a survey of south Florida vegetable growers. The *Vegetable Production Handbook for Florida*, on which nutrient BMPs are based, recommends 200 lb./ac. and 150 lb./ac. for tomato and watermelon, respectively.

The water table depth that was artificially raised using seepage irrigation was shallower (closer to the surface) for the grower-average system compared with the BMP system.

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The soil moisture level maintained for the grower-average system was determined from measurements taken at selected farms, while for the BMP system, the moisture level was kept around field capacity and managed based on measurements in crop beds. Crop yield data were collected for tomato and watermelon crops during multiple harvests. Water use, soil and plant tissue N content, and groundwater N concentrations for both grower-average and BMP systems were measured for the three-year period.

Figure 1. Tomato and watermelon grown/harvested during the irrigation and nutrient BMP study.
Credits: Sanjay Shukla, UF/IFAS

BMP Effects on Yield

There were no statistical differences in tomato yields across four growing seasons between the grower-average and BMP systems. Therefore, no adverse impact of reduced N rates was observed. However, the effect of fertilizer rates on watermelon yield varied widely between the two growing seasons. For the first season, no fertilizer effect on yield was established. But for the second season, significant differences were seen in yield where the average yield for the BMP system (203 cwt./ac.) was 41% lower compared with the grower-average system (345 cwt./ac.). The yield reduction for the BMP system was mainly due to an unusually wet spring that resulted in almost five inches of rainfall that started during the third week (Figure 2) after watermelon seedlings were transplanted. Heavy rainfall raised the water table up to the base of crop beds, dissolving and flushing out nitrogen (and potassium) from the beds (Figure 2). Results from watermelon leaf tissue analyses showed that N and K concentrations for the BMP system during the second season were always lower than the grower-average system. However, N concentrations for the BMP system remained within the sufficiency range, while K concentrations dropped well below the sufficiency range (about 50% lower than needed) 10 weeks after transplanting.

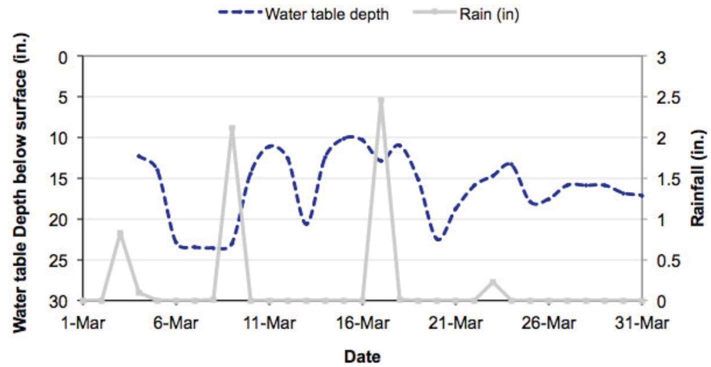

Figure 2. Daily water table and rainfall depth for grower-average system during the first month after watermelon seedling were transplanted (2/21/2005).

Soil Nitrogen Within and Below the Bed

Excess fertilizer N in crop beds, which was calculated as the difference between total fertilizer-N applied and N taken up by the plant, was consistently greater for the grower-average (2–5 times greater; 98–221 lb./ac.) compared with the recommended BMP system (20–129 lb./ac.) for both spring and fall seasons. Consistently greater amounts of leftover N in beds of the grower-average N-rate treatment indicated greater amounts of N were available for leaching compared with crop beds of the BMP N-rate treatment. Higher leftover N was supported by soil N (NO_2^- + NO_3^-) concentrations measured within crop beds for the grower-average rate (166 ppm), which were higher than the BMP rate (83 ppm). Higher residual N in the grower-average system indicated higher potential N leaching losses compared with the BMP system. Dissolved N (nitrate-N) concentrations measured in the soil water below crop beds (8 in.) were higher for the grower-average rate (27 ppm) compared with the BMP rate (18 ppm). The concentration of nitrate-N in the water leaving the crop bed was measured by analyzing dissolved N (nitrate-N and ammonia-N + ammonium-N) collected in small porous cups (soil solution sampler) placed in the soil. The soil water concentration of nitrate-N was 76 ppm for the BMP rate, which was 32% less than the grower-average rate (112 ppm). Overall, soil N analyses and soil solution concentrations within and below the crop bed (root zone) showed a higher mass of N leaving the grower-average system compared with the BMP system.

BMP Effects on Groundwater Nitrogen

The shallower water table depth (WTD) for the grower-average system resulted in several instances when the water table rose close to the row-middle areas and caused near saturation of the crop bed bottom. This occurrence is common in south and northeast Florida, especially during the fall growing seasons. Excessively wet bed bottoms for the grower-average system increased the N leaching potential compared with the BMP system. Higher N leaching in the grower-average system was confirmed by higher levels of total nitrogen (nitrate-N + ammonia-N + ammonium N + organic N) in groundwater. **The three-year average groundwater total nitrogen concentration for the grower-average (38 ppm) was more than twice the recommended BMP (16 ppm).** In addition to improved water quality, use of the BMPs also reduced water use by 8% compared with the grower-average system. This water saving was mainly obtained from using a lower water table depth than the grower-average system.

Economics

The prices of N, P, and K fertilizers during the beginning of the study were $0.45/lb., $0.68/lb., and $0.18/lb., respectively. Based on the fertilizer amounts reported in Table 1, the "grower" nutrient program for watermelons cost an additional $154 per acre as compared to the "recommended" nutrient program for each crop season ($317 [grower] – $163 [recommended]). During the second year, watermelon yields from the "grower" program produced statistically significant higher yields than from the "recommended" nutrient programs. At harvest, the price of watermelon ranged from $8.40 to $15.50 per hundred weight (cwt.). Table 2 summarizes the costs and benefits for the grower-average rate associated with yield differences between "grower" and "recommended" programs ranging from 130 to 150 cwt./ac. Low ($8.40/cwt.) and high ($15.50/cwt.) watermelon prices represented the range of market conditions that existed during the 2004 and 2005 seasons. Added fertilizer, harvesting, and marketing costs required for the grower-average rate (compared with the BMP rate) were considered for the upper and lower yield range. The break-even fruit price is the market price required to cover the total added cost for the grower-average rate. A partial budget analysis of the data revealed a strong economic motivation for nutrient application at the grower-average rates. **Under the conservative yield increase expectations and low market prices, the grower-average rate increased net returns by $590/ac. Under the combination of higher yield and price expectations, the gain in grower net return increased by $1,764/ac. (Table 2).**

Based on fertilizer amounts listed in Table 1 and prices prevalent during 2004–2006, the "grower" nutrient program for tomatoes cost $399 per acre each crop season. During the fall of 2004, the "recommended" nutrient program included 120 lb./ac. of P_2O_5, and the overall fertilization cost was $212 per acre or $187 less than the "grower" program. For the next three tomato seasons (fall 2005, spring 2006, and fall 2006), no P fertilizer was applied to the "recommended" fields because soil Mehlich-1 P levels were above the recommended sufficiency range. For the recommended system, the overall cost was $130 per acre or $269 less than the grower system. An analysis of tomato yield differences of the four crop seasons during the study period did not indicate statistically significant yield differences between the "grower" and "recommended" programs. One could argue that by following the "grower" program, a grower would have "wasted" nearly $1,000 in added fertilizer expenses over the four crop seasons. It should be kept in mind, however, that most growers view this added fertilizer as an "insurance" premium, since fresh market tomatoes are a high-valued product. If tomato prices had reached $20 per carton (25 lb./ctn.) for one week, a grower would only need to harvest an additional 50 cartons to more than offset the added fertilizer costs accrued over the entire four crop seasons.

Conclusion

Results of a two-year, four-crop-cycles experiment indicated that the recommended Best Management Practice (BMP) water and fertilizer nitrogen (N) rates for seepage-irrigated tomato in south Florida can reduce water use and N leaching to groundwater without adversely impacting yield. The same is true for watermelon for average rainfall conditions. However, wetter-than-average weather conditions can negatively impact watermelon yield. Economic analyses show that even under conservative yield and price expectations, the value of additional melon yields obtained during 2005 from the grower-average system (compared with the BMP system) covered the additional total cost for both the 2004 and 2005 seasons. The high value of fresh market tomatoes provides a significant economic incentive for growers to apply fertilizers at rates above recommended practices, as they confront extensive variability of growing and market conditions that can occur during a single season. Economic incentives of grower practices must be balanced against potential environmental impacts. Further research is needed to confirm whether the BMP rate of K_2O for watermelon is sufficient for production under unusually wet conditions in shallow water table production regions of Florida.

Nitrogen leaching can be reduced by lowering the water table and fertilizer-N rate as recommended by the BMP system. A lower water table and fertilizer-N rate reduces N-leaching by reducing the frequency of the water table reaching the crop beds and reducing nitrate-N in crop beds.

Compared with grower-average rates, BMP N fertilizer rates and irrigation management can reduce shallow groundwater total N concentrations by 45% to 58%. Since drainage accounts for most of the surface water flows from farms in the flatwoods region, surface water N loads from farms that implement the BMPs will be reduced. Basin-wide implementation of the recommended BMPs for tomato production can help meet target nitrogen loads for surface water bodies and reduce the associated environmental impacts on Florida's sensitive ecosystem.

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Table 1. Nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) fertilizer rates, and soil moisture (volumetric %) levels for watermelon and tomato during each season for grower-average system (grower water and inorganic fertilizer N [N_{fert}] rate with seepage irrigation) and the recommended BMP system (recommended water and N_{fert} rate with seepage irrigation).

		Watermelon			Tomato			
Treatment	**Season**	**N**	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**	**Moisture Content**
		lb./ac.						**v/v**
Grower-average	All seasons	265	170	459	373	162	673	0.16–0.20
Recommended (BMP)	Spring 04	150	100	150	—	—	—	0.08–0.12
	Fall 04	—	—	—	200	120	224	0.08–0.12
	Spring 05	150	100	150	—	—	—	0.08–0.12
	Fall 05	—	—	—	200	0	224	0.08–0.12
	Spring 06	—	—	—	200	0	224	0.08–0.12
	Fall 06	—	—	—	200	0	224	0.08–0.12

Table 2. Partial budgeting analysis for watermelon across a range of yield and price expectations considering grower-average vs. BMP inputs during 2004 and 2005. High yield gain values (150 cwt./ac). and low yield gain values (130 cwt./ac). represent the maximum and minimum differences, respectively, between watermelon yields of grower-average and BMP rates.

			Dollars/acre	
		Cost/cwt.	**Low yield gain (130 cwt./ac.)**	**High yield gain (150 cwt./ac.)**
Added cost of grower-average rate	Harvest and marketing	$2.95	$383	$442
	Higher fertilizer cost[a]		$119	$119
Total added cost			$502	$561
Break-even price[b]			$3.86/cwt	$3.74/cwt
Added benefit of grower-average rate	Low watermelon price[c]	$8.40	$1,092	$1,260
	High watermelon price[c]	$15.50	$2,015	$2,325
Benefit–cost	Low watermelon price[c]	$8.40	$590	$699
	High watermelon price[c]	$15.50	$1,513	$1,764

[a] Grower-average = 265, 170, and 459 lb./ac. of N, P_2O_5, and K_2O at $0.45/lb., $0.68/lb., and $0.18/lb., respectively. BMP = 150, 100, and 150 lb./ac. of N, P_2O_5 and K_2O at $0.45/lb., $0.68/lb., and $0.18/lb., respectively.
[b] Break-even price calculated by dividing total added cost by expected yield gain.
[c] Florida Agricultural Statistics Service, 2006.