BMP—Recommended Water and Phosphorus Inputs for Tomato and Watermelon Can Reduce Environmental Losses of Phosphorus and Save Water

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Introduction

Phosphorus (P) is an essential nutrient for vegetable as well as other crops. Phosphorus is required for the commercial production of tomato and watermelon, two important crops in Florida with regards to area and economic impact (FDACS 2010). The average P fertilizer rate reported for Florida for tomato is 80 lb/ac (Hochmuth et al. 1999), while watermelon has been reported to receive 58 lb/ac (Hochmuth et al. 1993). Both these crops are grown on raised plastic mulch beds. Most of the acreage of these two crops is irrigated with drip irrigation or seepage irrigation with the latter being a more popular system because of its low cost and perceived uniformity in maintaining needed soil moisture within the entire bed.

Phosphorus is an important nutrient for plants, but when it is applied beyond plant need, it has the potential to increase P surplus in soil. A surplus of P can lead to enrichment of downstream waters and can adversely impact ecosystems such as the Florida Everglades. This surplus becomes especially important for farms where multiple crops (fall/winter/spring) are grown within a year on the same land. An example of this would be tomato grown during the fall season (September–December) followed by watermelon in the spring (March–May). Seasonal P fertilizer applications for vegetable production can add to the P surplus identified for most of Florida. South Florida, the main vegetable production region in Florida (especially for tomato, pepper, and watermelon), has been identified as one of the significant P surplus regions of the world (MacDonald et al. 2011).

Unlike heavier soils where most of environmental losses of P occur through runoff, the sandy nature of Florida soils makes them susceptible to significant losses of P through leaching. Phosphorus that leaches below the plant root zone can quickly reach the groundwater in regions where the water table is close to the surface. Shallow groundwater regions include most of South Florida and northeast Florida. In these regions, P leaching to the groundwater becomes especially important because the majority of discharges of water and dissolved nutrients from farms are from subsurface drainage through ditches. Phosphorus leaching from sandy agricultural soils of shallow water table areas has the potential to adversely impact P-limited freshwater ecosystems of south Florida such as Lake Okeechobee and the Florida Everglades.

State agencies in cooperation with the Institute of Food and Agricultural Sciences at the University of Florida (UF/IFAS) and the vegetable industry have developed Best Management Practices (BMPs) for vegetable production. The
BMP manual is available at http://www.freshfromflorida.com/content/download/32110/789059/Bmp_VeggieAgro-Crops2005.pdf. Although these BMPs include numerous practices, the use of UF/IFAS-recommended fertilizer application and soil-moisture-based irrigation management are the key practices when it comes to the level and management of water and nutrient inputs. Nitrogen fertilizer recommendations are based on crop needs as found in the literature and not from a soil test, but recommendations for applying P are based on soil test P (e.g. Mehlich 1 or Mehlich 3). For irrigation management, growers can select any of several approaches (e.g. soil moisture measurements, evapotranspiration) for maintaining the appropriate soil moisture. The primary goal for developing these BMPs is to reduce the impacts on downstream water quality while maintaining the financial viability of agriculture. However, limited information is available on the effectiveness of these BMPs in reducing the nutrient (e.g. P) loads. Growers are concerned about the impact of these recommendations on their production and farm income. Another question often asked by the industry as well as other stakeholders is how and to what extent these BMPs actually reduce the P losses.

We summarize the results from one of the first studies in Florida, which takes a systems approach to evaluate the effects of water and nutrient (P) BMPs on not only yield but also water use and P losses to the groundwater for seepage-irrigated tomato and watermelon production systems. Management of water involved controlling the water table depth for seepage irrigation to keep optimum soil moisture in the root zone. Seepage irrigation is a common irrigation method for vegetables in south and northeast Florida.

**BMP Study**

A BMP study was conducted at the research farm of the UF/IFAS Southwest Florida Research and Education Center in Immokalee, FL. The study evaluated two production systems made up of two levels of water and fertilizer inputs for tomato and watermelon production with seepage irrigation (Figure 1). The average water and P fertilizer rates used by growers (grower-average) in south Florida were contrasted with the recommended BMP rates (Table 1). Tomatoes were produced for four seasons (spring and fall) (Table 1) while watermelon was grown for two (spring). The grower-average fertilizer rates and irrigation management were determined from a survey of growers and on-farm measurements of soil moisture, respectively. The grower-average P fertilizer rates for tomato and watermelon were 162 lb P₂O₅/ac and 170 lb P₂O₅/ac, respectively. The BMP rates for tomato and watermelon were based on the Mehlich-1 soil P test. Higher soil moisture levels were maintained in crop beds for the grower-average system by maintaining a higher water table that resulted in soil moisture similar to those measured at vegetable farms in south Florida. Water management for the BMP system involved maintaining a water table that resulted in optimum soil moisture. Watermelon was grown during the spring of 2004 and 2005, while tomato was grown during the fall of 2004, 2005 and 2006, and spring 2006. Whole plant and soil (within raised beds covered with plastic mulch) were collected for each crop season and analyzed for P concentrations. Groundwater samples were collected from wells on a bi-weekly basis and analyzed for total P (TP) concentrations. Further details of the study can be found in Hendricks, Shukla, Obreza, and Harris (2014).

![Figure 1. Tomato and watermelon grown/harvested during the irrigation and nutrient BMP study. Water Resources Program, UF/IFAS Southwest Florida Research and Education Center, Immokalee, FL. Credits: Sanjay Shukla, UF/IFAS](image)

**Crop Yield**

For tomato, no yield advantage was detected across the three systems (two P rates) over four growing seasons, indicating that no adverse impact of reduced fertilizer P rates occurred. Yield effects for watermelon varied across the two seasons. In the first season there was no difference in yield, while for the second spring season, yields for the grower average fields were statistically higher compared with BMP fields. This was mainly due to a wetter-than-average spring that resulted in a sustained high water table, which caused excessive leaching of both potassium and nitrogen from the raised beds. This was confirmed by lower-than-sufficient levels of K in the leaf tissue. However, no effect of P fertilizer rates on yield could be established. Although P concentrations in the leaf tissue for the BMP systems were lower than the industry average, they were within the recommended sufficiency range for watermelon. Results for the effects of nitrogen recommendations on production, farm income, and nitrogen leaching and ground water concentrations are available in another publication (see EDIS AE503).
Soil and Groundwater P Concentrations and Water Use

Despite a 35% higher P rate applied for the average tomato grower system (162 lb $P_2O_5$/ac) compared with the BMP (120 lb $P_2O_5$/ac) systems, Mehlich 1 P values remained similar as long as both systems received P fertilizer. Mehlich 1 levels stabilized around 55 mg/kg (ppm) for the BMP system and showed a gradual decrease after P application stopped. However, Mehlich 1 P levels steadily increased with sustained fertilizer P application rates in each season in the grower average fields, reaching a high of 145 ppm by the end of the study (sixth crop season).

Groundwater total P concentrations were positively correlated with Mehlich 1 P levels. Average TP concentration in the groundwater for the grower average fields was 3.09 parts per million (ppm) or milligram/liter. For the BMP fields, the average TP concentrations was 2.10 ppm, 32% less than the grower average.

In addition to reducing P leaching to groundwater, the BMP systems also used 8% less water than the grower average systems. Interestingly, the 32% percent reduction in TP concentrations for the BMP system is relatively close to the 26% percent lower fertilizer P input for the BMP system compared to the grower average. The differences in Mehlich-1 P levels between the BMP fields and grower average remained even after six years (2012) after the study ended. During these six years no additional fertilizer P was applied. Mehlich-1 P measured six years after the study still showed relatively high levels, a legacy effect of fertilizer P applications. The main factors influencing groundwater P concentration varied by seasons. During fall with frequent rainfall, the concentrations were correlated with Mehlich-1 P and fertilizer P levels. During the dry period of spring, water table depths and rainfall also became important factors in affecting the leaching. Overall, results indicated that managing the fertilizer P and irrigation input can help reduce the P losses to groundwater. The nature of irrigation (groundwater depth) and the fact that flows from the drainage ditches are mainly derived from the groundwater, water and nutrient BMPs are likely to reduce the surface water P loads (volume multiplied by the P concentration) from the farms.

Conclusion

Applying BMP-recommended water and phosphorus (P) inputs for seepage-irrigated tomato and watermelon in Florida can reduce water use and P leaching to groundwater without adversely impacting fruit yield. However, given the adverse impacts on watermelon yield due to lower than sufficient levels of K, further research is needed to evaluate the fertilizer recommendations for watermelon, especially $K_2O$ rates, to ensure economic viability of farms. Our results showed that adoption of BMP-recommended P rates as a BMP did not reduce crop yield and improved water quality. Reductions in groundwater TP concentrations by 32% by following soil test-based fertilizer P rates will also reduce the P loads from the farms to the downstream waterbodies.

Acknowledgement

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References


Table 1. Nitrogen (N), phosphorus (P$_2$O$_5$) and potassium (K$_2$O) fertilizer rates, and soil moisture (volumetric %) levels for watermelon and tomato during each season for grower-average system (grower water and fertilizer P rates with seepage irrigation) and the recommended BMP system (recommended water and fertilizer P rates with seepage irrigation).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Season</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grower-average</td>
<td>All seasons</td>
<td>265</td>
<td>170</td>
<td>459</td>
<td>373</td>
<td>162</td>
<td>673</td>
<td>0.16–0.20</td>
</tr>
<tr>
<td>Recommended (BMP)</td>
<td>Spring 2004</td>
<td>150</td>
<td>100</td>
<td>150</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.08–0.12</td>
</tr>
<tr>
<td></td>
<td>Fall 2004</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>200</td>
<td>120</td>
<td>224</td>
<td>0.08–0.12</td>
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<tr>
<td></td>
<td>Spring 2005</td>
<td>150</td>
<td>100</td>
<td>150</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0.08–0.12</td>
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<td></td>
<td>Fall 2005</td>
<td>--</td>
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<td>--</td>
<td>200</td>
<td>0</td>
<td>224</td>
<td>0.08–0.12</td>
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<tr>
<td></td>
<td>Spring 2006</td>
<td>--</td>
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<td>200</td>
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<td>Fall 2006</td>
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<td>--</td>
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<td>200</td>
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