Keeping Water and Nutrients in the Root Zone of Vegetables

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Summary and action items:

The success of the BMP program for vegetables in Florida is measured by the level of BMP implementation and the improvement of water quality. Both require keeping water and fertilizer in the root zone of vegetables. The following priorities, recommendations and vision are made by the UF/IFAS Extension Vegetable group to the state agencies to help the vegetable industry successfully transition into the BMP era:

Basic principles:

1- ***Base UF/IFAS production recommendations on the rigors of science and the reality of field production***
2- ***Replace the out-of-date paradigm "Pollute less by reducing nutrient application rates" with "Improve water management and adjust fertilizer programs accordingly".***
3- ***Engage together growers, consultants, educators and regulators in open-channel discussions.***

UF/IFAS fertilizer and irrigation recommendations:

4- ***Fertilization and irrigation recommendations for vegetable grown in Florida are detailed and research based, but need updating. UF/IFAS fertilizer rate studies should be conducted regularly with Florida major crops to reflect current varieties used by the industry. This research should be a funding priority by Florida Department of Agriculture and Consumer Services because of the legal consequences of third party agencies adopting UF/IFAS fertilizer rates.***

Nutrient load determination:

5- ***In-field load assessment should be considered another funding priority by the Florida Department of Agriculture and Consumer Services, the Florida Department of Environmental Protection, and the fie Florida Water Management Districts. An increased fertilizer rate does not directly translate***

into an increase in load. This first requires the development of reliable methods and tools (drainage lysimeters) of know precision because watershed-level load simulations are poor indicators of field-level leaching.

New techniques that keep nutrients in the root zone that should be considered for funding:

6- Develop ultra-low flow drip irrigation

7- Convert from seepage to drip irrigation

8- Use recycled water

9- Develop controlled-release fertilizer for N for seepage-irrigated crops (tomato, bell pepper, eggplant, watermelon, cabbage)

10- Develop management tools based on real-time, continuous soil water and chemical parameters

11- Develop yield mapping tools for vegetable crops

Zero discharge systems:

12- Spodosols are in theory zero-discharge systems when it does not rain, but leaching rains are common in Florida, especially in the Fall

13- Greenhouses are most suitable for nutrient and water recycling and reuse

14-For crops grown with drip irrigation, zero-discharge may be approached using ultra-low flow drip-tapes to match water application rate and hourly ETc, reducing or eliminating preplant fertilizer.

Breeding for improvement nutrient uptake efficiency (NUE):

15-UF/IFAS breeding programs and UF/IFAS administration should support breeding for improved NUE.

16- Possible strategies for developing commercially-acceptable varieties with improved NUE include improving morphological, biochemical and chemical traits.

17- The application of grafting in developing commercially-acceptable varieties with improved NUE should be supported.

All these strategies should be pursued simultaneously and financially supported.

Coordination and funding structure:

18- UF/IFAS Extension should lead educational programs on BMPs while closely working with researchers, state agencies and the industry

19- Results of UF/IFAS research should be promptly reported in the scientific literature for scientific use and recommendation update

20- A 5-year research and outreach plan should be developed by UF/IFAS faculty members with active programs in vegetable BMP under a state-wide Hatch project

21- State agencies should develop a funding model that allows the funding of multi-year projects

22- A state-wide BMP conference focusing on vegetables should be organized every 3 years

23- FDACS should consider developing and implementing a "fertilizer applicator licence" following the existing model for pesticides. Educational credits should be available at the beginner and advanced levels.

Introduction

Best Management Practices (BMP) are cultural practices that aim at improving the quality of Florida waters while maintaining or improving productivity (FDACS, 2005). Because water is the carrier of soluble nutrients and sediments, the overall goal of BMP implementation is to keep water and nutrients in the root zones of vegetables. This report (1) describes the typical nutrient management systems used in Florida for vegetable crop production, (2) compiles known estimates of nutrient load, (3) discusses the feasibility of zero-discharge systems for vegetables, (4) provides insight on the potential role of breeding and grafting on improving vegetable crop nutrient use efficiency, and (5) develops a vision on what the Florida vegetable industry at-large could do to improve water quality. Each section also provides a summary and action item that state agencies involved in BMP (the Florida Department of Agriculture and Consumer Services, the Florida Department of Environmental Protection, the five water management districts of Florida and UF Institute of Food and Agricultural Sciences) may find useful in planning and coordinating funding allocation, identifying future research needs, and supporting educational programs.

First action item: Keeping water and nutrients in the root zone.

Base irrigation and fertilization recommendations on the rigors of science and the reality of field production

Replace the out-of-date paradigm "Pollute less by reducing nutrient application rates" with "Improve water management and adjust fertilizer programs accordingly".

1. Situation

1.1 What are the typical nutrient and water management practices used by Florida producers?

a. Diversity of vegetable production systems used in Florida. Vegetables are grown in Florida on three main types of soils (sandy soils, organic soils, and calcareous soils), using two main types of irrigation methods (drip irrigation and/or seepage irrigation), two main types of production systems (bare ground or mulched crop), and three seasons (Fall, Winter, and Spring). Overhead irrigation is also used in North Florida and Miami-Dade County. This diversity creates a wide array of production systems over varying weather conditions, each having its own requirements for water and nutrient management. These systems were recently reviewed in a white paper published by the UF/IFAS Vegetable Fertilizer Task Force (Cantliffe et al., 2006).

b. UF/IFAS fertilizer recommendations. Crop-by-crop fertilizer recommendations for vegetables grown on sandy soils may be found in the Vegetable Production Handbook for Florida. UF/IFAS fertilizer recommendations include a base fertilizer rate and a supplemental application allowed after a leaching rain (defined as 3 inches of rainfall in 3 days or 4 inches in 7 days), an extended harvest season, and/or when plant nutritional status is diagnosed as "low" based on whole leaf analysis or petiole sap testing. UF/IFAS fertilizer recommendations for vegetables also include fertilizer placement (banded, broadcast, or modified broadcast), fertilizer sources when necessary, pre-plant fertilizer application amounts, and fertigation schedules.

Fertilizer recommendations, based on research from the 1980s and 1990s, propose a single nitrogen (N) rate for all irrigation systems, production seasons and Florida soil types (Hochmuth and Cordasco, 2000a,b,c,d,e,f; 2003a,b,c). Recommendations for P, K, Ca, Mg and micronutrients applications on sandy soils are based on Mehlich 1 soil test results. Recent updates to UF/IFAS fertilization recommendations from the UF/IFAS Vegetable Fertilizer Task Force were approved and will be incorporated into the next revision of the Vegetable Production Handbook in June/July 2008. Updated fertilizer recommendations include (1) adopt preliminary N recommendations for drip-irrigated grape tomato, (2) report lack of efficacy of foliar-applied calcium sprays to improve strawberry yields and postharvest quality, and (3) increase by 25% N fertilization recommendation for seepage-irrigated crops to compensate for denitrification losses.

Recommendations for vegetable crops grown on muck soils may be found in "Fertilization recommendations of crisphead lettuce grown on organic soils (Hochmuth et al., 2003a) and "Fertilization of sweet corn, celery, Romaine, escarole, endive, and radish on organic soils in Florida" (Hochmuth et al., 2003b).

Fertilizer recommendations for vegetable crops grown on the calcareous soils of south Miami-Dade County are at this point incomplete because no calibrated soil test is available for the area (Li et al., 2006a,b,c,d,e,f,g,h,i,j). In the absence of a calibrated soil test for this Florida soil type (AB-DTPA is under consideration), fertilizer recommendations and, hence, practices are based on experience and results of whole leaf analysis and/or petiole sap testing.

c. UF/IFAS irrigation scheduling recommendations: Irrigation recommendations for vegetable crops grown with seepage irrigation are to maintain the water table at the 6-12 inch-depth when plants are small and at the 18-24 inch-depth when plants are fully grown. Irrigation recommendations for vegetables grown with overhead and drip irrigation include (1) an ET-based target volume, (2) fine-tuning volume based on soil moisture level, (3) splitting irrigation to limit water movement below the root zone, and (4) keeping records of irrigation practices (Simonne et al., 2007a).

As recommended by the UF/IFAS Vegetable Fertilizer Task Force, research results on fertilizer and irrigation management developed in the context of the BMPs and published in refereed journal articles since the early 2000s need to be incorporated into UF/IFAS recommendations (Cantliffe et al., 2006).

Second summary and action item: UF/IFAS fertilizer and irrigation recommendations. Fertilization and irrigation recommendations for vegetable grown in Florida are detailed and research based, but need updating. UF/IFAS fertilizer rate studies should be conducted regularly on Florida major crops to reflect current varieties used by the industry. This research should be a funding priority by Florida Department of Agriculture and Consumer Services because of the legal consequences of third party agencies adopting UF/IFAS fertilizer rates.

1.2. Do we have data describing the magnitude of nutrient leaching or runoff resulting from typical management practices?

a. Definition and methods for load measurement (Gazula et al., 2006)

Quantifying nutrient load from vegetable production systems is the first step towards monitoring and understanding groundwater pollution in the field. A nutrient load is defined as the mass of a chemical entering or leaving an area, and it is calculated as the product of the volume of water that the chemical is transported in and the concentration of the chemical in the water (Rice and Izuno, 2001). Past research has focused mostly on improving estimation of nutrient concentration, and several assumptions are often made in determining the corresponding volume of water on a per acre basis. This is important for vegetable crops grown on raised beds because the leaching or wetted surface depends on bed compaction, width and spacing (Farneselli et al., 2008). Load estimates may vary from simple to double based on the assumptions made on the size and shape of the wetted zone (Farneselli et al., 2008). Since nutrient concentration and size/shape of the wetted zone are equally important in in-field load determinations, they should be estimated with the same level of accuracy.

Nutrient load can be determined indirectly or directly. The indirect approaches of measuring load include nutrient flow models and nutrient balances. Nutrient flow models are important tools for evaluating the impact of nutrient leaching on water quality at the watershed level, and play an important role in designing agricultural and environmental policies. Direct methods for calculating load at the field level are resin traps, soil sampling, or drainage lysimeters. While each of these methods has its own advantages and limits (Gazula et al., 2006), it appears that small, in-row drainage lysimeters are emerging as a practical tool for direct load measurements (Gazula et al., 2006; Migliaccio et al., 2006; Dukes et al, unpublished data; Stanley et al., unpublished data; Williamson and Haman, unpublished data). A permanent vacuum may be added to low-cost drainage lysimeters to prevent water logging without compromising the accuracy of the results (Evett et al., 2006). At 0.0013 mm, accuracy of drainage measurement was nearly two orders of magnitude better than that of the lysimeter mass measurement (1 mm), ensuring that the continuous drainage measurement may be included in the mass balance determination of evapotranspiration (ET) without diminishing the accuracy of ET values (Evett et al., 2006).

b. Published load estimates: Few in-field load estimates have been published for vegetables, and few of those were developed on sandy soils applicable to Florida (Table 1). Load estimates ranged from 1 to 400 kg/ha of N, and varied based on crops, cultural practices, and irrigation/fertilizer management, but also based on the methodology used for extrapolating load calculations to a per-acre basis. Hence, efforts should be made to standardize protocols and methodology for in-field load estimation. In addition, the link between irrigation management and nutrient leaching shows that education on irrigation and nutrient management is central to BMP implementation.

Third summary and action item: nutrient load determination.
In-field load assessment should be considered a funding priority by the Florida Department of Agriculture and Consumer Services, the Florida Department of Environmental Protection, and the fie Florida Water Management Districts. An increased fertilizer rate does not directly translate into an increase in load. This first requires the development of reliable methods and tools of known precision because watershed-level load simulations are poor indicators of actual field-level leaching. The effect of all fertilizer recommendations on nutrient load should be determined for all major vegetable crops through on-farm research projects in regionally appropriate production areas.

2. Fertilization and nutrient management

2.1 What do we know about water and nutrient sources, application rates, timing, application methods, and crop response?

Extensive fertilizer work has been done with vegetables in Florida since the 1960's by S.J. Locascio, E. Hanlon, G.J. Hochmuth, G. Geraldson, C. Sanchez and others, and published in the Journal of the American Society Horticulture Science, HortScience, HortTechnology, the Proceeding of the Florida State Horticultural Society and the Soil and Crop Science Society of Florida. These results are the foundation of the current recommendations that are based on the use of soluble fertilizers.

Limited information is available on the use of controlled-release fertilizers, except for potato (Hutchinson, 2004; Pack et al., 2006; Simonne and Hutchinson, 2003). An on-going project is assessing tomato and bell pepper response to CRFs. Research on developing CRF-based fertilization programs should be supported for all the main crops grown with seepage irrigation (potato, tomato, bell pepper, eggplant, watermelon, cabbage).

2.2 What strategies do producers use to schedule irrigation and monitor crop nutrition?

Vegetable growers use on-farm weather data, soil test, soil moisture-sensing devices (mostly drip- and overhead- -irrigated crops), water-table monitoring tools (seepage-irrigated crops), whole-leaf analysis and/or petiole sap test to schedule irrigation and monitor crop nutrition. Success stories on how these tools have helped improve on-farm water and nutrient management have been reported with cucurbits (Simonne et al., 2005) and strawberry (Hochmuth et al., 2003c).

2.3 What are the specific production system effects on water and nutrient use efficiency?

Water and nutrient use efficiency vary from situation to situation, but in theory, drip irrigation allows for a more efficient use of water and nutrients when properly managed.

2.4. What new practices could producers implement that would improve water use and decrease nutrient loss?

The main technically feasible practices could include (1) switching from seepage to drip irrigation, (2) identify adequate release pattern from controlled-release fertilizers for seepage-irrigated crops, and (3) develop ultra-low flow drip-tapes for drip irrigation. In theory, keeping the water in the root zone of vegetable crops could be achieved by having an adjustable flow-rate emitter (by changing operating pressure) which flow rate could match hourly ETc. The feasibility of achieving ultra-low flow rates (8 to 12 gal/100ft/hr) by operating current emitters at lower pressures or developing new emitters needs to be supported and pursued. This may require the development of partnership with irrigation-supply manufacturers. Also, the effects of low pressure on uniformity and filtration requirements need to be addressed to reduce clogging risk. Ultra-low flow drip irrigation is, in our opinion, the strategy that has the greatest potential to simultaneously keep the water in the root zone of vegetable crops and reduce water use. The economical feasibility of implementation of each of these practices also needs to be determined. In addition, (4) real-time, continuous sensing of soil moisture status, soil EC, and nutrient concentrations, (5) yield mapping as a basis for nutrient application, and using recycled water need to be considered. In doing so, fertilizer and irrigation management need to be considered within a production system (and not as independent parameters that can be changed as needed) and the cost of each new technique needs to be related with the value of the information provided to the grower. The development of new soil nutrient sensors and yield mapping techniques, offers the attractive prospective of reducing the need for soil sampling and of linking field heterogeneity to nutrient management. Real-time field data could be used as "BMP intelligence".

Fourth summary and action items: New techniques that keep nutrients in the root zone that should be considered for funding:

- develop ultra-low flow drip irrigation
- convert from seepage to drip irrigation
- use recycled water
- develop controlled-release fertilizer for N for seepage-irrigated crops
- develop management tools based on real-time, continuous soil water and chemical parameters
- develop yield mapping tools for mulched crops

3. Zero discharge systems

3.1 Are zero discharge systems practical and economically feasible?

In theory, spodosols allow for a natural zero-discharge system when the spodic layer is continuous and in the absence of rain. In short, spodosols have an impermeable layer that transforms a field into a giant bathtub. When it rains, water needs to be pumped out of the field to prevent the bathtub from filling up. Currently, a zero-discharge system on deep sand soils does not seem technically feasible in field production (past attempts to create physical barriers of concrete or plastic have failed). In contrast, it can be done, relatively simply in greenhouse production. Attempts to modify soil water holding capacity in open fields by using organic (compost, modified-corn starch, polyacrylamides) or inorganic (zeolites) amendments are economically and technically not feasible due to the large quantities of material needed (Bhardwaj et al., 2007; Sivapalan, 2006; Sepaskhah and Yousefi, 2007; Vavhere et al., 2003).

Cover crops are often presented as an under-used BMP tool. Cover crops may be used to compete with weeds (Linares et al., 2008), return biomass and nutrients to the soil (Munoz et al., 2008; Schomberg et al., 2007), and retain pesticide residues (Potter et al., 2007). However, cover crops are not used as often as expected because more research is needed to (1) identify suitable cover crops for different seasons in Florida, (2) assess the role of a cover crop in the life cycle of crop pest (disease, insects and virus pests), and (3) quantify the real capability of nutrient scavenging of each cover crop. Cost and seed availability are also cited as impediments to a broader use of cover crops.

Hence, because of the low water holding capacity of Florida sandy soils and unpredictable rainfall patterns, zero discharge in field production should be considered an approachable, yet not reachable goal.

3.2 What equipment and technology are required to create a zero discharge system?

Catch ponds are sometimes used to collect excess rainfall in seepage irrigated systems. However, ponds represent a large capital investment and permanently occupy land. The use of polyacrylamide blocks or zeolite filters located at key structures/discharge points have shown promise to trap soluble nutrients and sediments in arid environments (Zreig et al., 2007). Up to date, limited research has been conducted by UF/IFAS on this topic, but engineering firms have successfully used this technology on construction sites throughout Florida. However, peak volumes during storm events may be excessively large on commercial operations, thereby limiting this practice.

Zero-discharge systems in mulched and drip–irrigated fields with deep sandy soils may be approachable if drip irrigation application rates can match hourly ETc rates. This will require slight modification of existing systems (filters and pipes) and the development of ultra-low flow drippers (see above).

Fertilizer programs (mostly N) for vegetables need to be developed using controlled-release materials.

Fifth summary and action items: zero discharge systems.
Spodosols are in theory zero-discharge systems when it does not rain
Greenhouses are most suitable for nutrient and water recycling and reuse
Ultra-low flow drip-tapes could be used to match water application rate and hourly ETc

4. Plant breeding and genetics

Most public breeding programs focus on developing parents for hybrids while private breeding programs mostly produce industry-ready varieties. With the exception of N-efficient potato varieties from Europe, improved nutrient use efficiency (NUE) is rarely the main focus of either type of vegetable breeding programs. Overall, breeding for improved pest resistance is the main focus. By using high fertility rates in breeding programs, little emphasis is placed on "passively" selecting for high NUE varieties. Hence, public and private breeding programs will have to be committed to NUE in the parents and new commercial varieties released.

Efforts to improve nutrient use efficiency have been conducted in the last 40 years on food crops of world-wide importance such as rice, wheat, corn and beans, with emphasis on horticultural productivity and nutritional quality of the harvested plant part. Differences in nutrient uptake patterns among genotypes within a genus are known for many vegetable crops including tomato (O'Sullivan et al., 2006; JianJun and Gabelman, 1995), cabbage (JinKiu et al, 2006; Tanaka and Sato, 1997), potato (Shahnazari et al., 2008; Sharifi et al., 2007; Sharifi and Zebarth, 2006), and pumpkin (Swiader et al., 1994). However, the focus of these research projects was mostly to document phenotypical differences or to improve the adaptation of current lines to areas of poor growing conditions (such as salinity or micronutrient deficiencies), rather than identify genes involved in nutrient uptake. Breeding approaches that may increase plant nutrient use efficiency include (1) anatomical modifications of root system architecture (increased branching and number of small, absorbing roots; Munoz-Arboleda et al., 2006; Frith and Nichols, 1975; Beebe et al., 2006; XiangRong et al., 2005), (2) chemical modification of the soil around the roots that increase the availability nutrients [release of phosphatases that make P more available (George et al., 2005) or citrate that lower and buffer the pH near the roots (Shenk, 2006)], (3) biochemical modification of the root surface by increasing the number of absorption sites on each root; Cuartero and Fernandez-Munoz, 1999), and (4) understanding the regulation of genes involved in nutrient uptake (Chao et al., 2007).

With all the plant physiology knowledge developed since the 1970's and the recent progress in genomics, breeding for root systems with improved NUE may become a reality. It will require the commitment of the UF/IFAS breeding programs and the identification of all the genes that code for the phenotype of interest. Projects should link together soil chemistry, plant biochemistry, plant physiology and genomics. While this type of effort may contribute to BMP efforts and improvement of water quality, the full funding of these long-term, basic projects may be beyond the scope of funding by the Florida agencies involved in BMPs. However, these agencies could partially support these projects.

Traditionally, breeding has focused on improving the genotype of a single (open pollinated) or two (hybrid parents) individuals. Vegetable grafting is an innovative technique successfully practiced in Asia that develops a new plant by physically uniting two plants (the rootstock and the scion) through the graft. Resistant rootstocks, grafting methods and procedures are being developed primarily on solanaceous (tomato, eggplant) and cucurbit (watermelon, melon, cucumber) crops for management of soil borne pathogens such as *Fusarium*, *Verticillium*, and nematodes. In addition to disease control, grafted plants have shown tolerance to environmental stresses such as low temperature and salinity (Estañ et al. 2005; Lee 1994, 2003). As grafted vegetables often exhibit significant yield increases as a result of vigorous growth even in the absence of disease pressure, it is possible that grafting may enhance water and nutrient uptake by plants (Khah et al. 2006; Lee 1994, 2003; Qaryouti et al. 2007). Hence, grafting may help speed the developments of nutrient and water efficient plants. If the commercial plant material targeted is a grafted transplant, a novel approach to plant breeding could be to separately develop hybrid rootstocks and hybrid scions. Economical analysis will have to establish the break-even point between the environmental benefit and the cost of labor and seed associated with grafting before this technique is adopted by the industry.

Sixth summary and action items: breeding in the BMP era.

UF/IFAS breeding programs and UF/IFAS administration should support breeding for improved NUE.

Possible strategies for developing commercially-acceptable varieties with improved NUE include morphological, biochemical and chemical traits.

The application of grafting in developing commercially-acceptable varieties with improved NUE should also be supported.

All these strategies should be pursued simultaneously and financially supported.

3. Vision for the next 5 years: what does the industry need to do better?

Industry progress in irrigation and nutrient management in the near future is likely to depend on general economical context (production costs, food safety issues, labor availability) and on educational programs. The BMP process so far has focused on the land owner and/or on the grower. However, the commitment of the consulting and fertilizer industry to BMPs and water quality also needs to be strengthened. Similarly to what was developed for pesticides in the 1970's, a fertilizer applicator's license program coordinated by FDACS and educationally supported by IFAS should be developed based on the existing Certified Crop Advisor program. In a state like Florida where UF/IFAS is not the sole direct source of information for the growers, it is essential that all segments of the vegetable industry be involved in the BMP program.

The mobile irrigation labs (MIL), the BMP implementation teams and local Extension offices should be supported and given the resources necessary to fully utilize their knowledge, experience, credibility and connection with the growers to ensure a rapid adoption of BMPs by the vegetable industry in Florida.

a What are the gaps in current knowledge? See Table 2

b What questions need to be answered by research? See table 3 and 4

c What educational programs are needed? See tables 3 and 4

d What are the critical issues on the horizon that may affect the industry? See tables 3 and 4

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Table 1. Published nutrient load estimates for selected crops.

Crop	Method used for load estimation	Load estimate	Reference
'Hamlin' orange	- Polyethylene drainage lysimeter tanks - NO_3-N and NH_4-N concentrations were multiplied by total leachate volume pumped to estimate the total N leached below root zone during collection period.	N concentrations ranged from 27 to 86 mg/L and N loads ranged from 174 to 252 g/lysimeter based on frequency of fertigation.	Syvertsen and Jifon, 2001
Processing tomato	- Ceramic cups installed at 1-m depth - Nitrate leached was calculated as the product of mean nitrate concentration in the soil solution at 1-m depth and the volume of drainage estimated by water balance.	Total N leached ranged 155 to 421 kg N/ha based on irrigation schedule.	Vázquez et al., 2006
Field tomato	- Red sandy loam - Soil samples were collected from 0-60 cm soil depths	Total residual N in the soil ranged from 38 to 98 kg/ha depending on the soil depth and fertilizer treatment.	Hebbar et al., 2004
Field tomato	- Blanton Foxworth Alpin soil complex - Soil sampling was done from 0-5 ft depth.	Total N load during 2005 and 2006 ranged from 0.1 to 21 kg/ha depending on bed width and fertilizer-irrigation rates.	Gazula et al., unpublished data

Table 2. Summary of current BMP research areas for vegetable crops, level of knowledge, gaps.

BMP research area	Level of knowledge	Gaps
Fertilizer recommendations	Foundation work complete for major crops Limited or incomplete for herbs No fertilization recommendations for organic vegetable production	Need regular updates Need provisions for ENSO phases and expected frequency of leaching rainfall Need to abandon single-number recommended rates Education need to focus on reducing preplant rates with drip Need to support work All work on organics needs to be done
Irrigation recommendations	Seasonal water use estimates complete for major crops	Need automated, sensor based irrigation systems Need to match irrigation zones to soil type Need to rename "reclaimed water" with "recycled water"; then need to generalize the use of recycled water as irrigation water: nutrient contribution and food safety aspects need to be clarified Demonstrations needed to show reduced irrigation when plants are small
Fertilizer recommendations for the use of controlled-release fertilizer	Advanced for seepage-irrigated potato. Work underway on tomato and bell pepper	Work needed for all seepage irrigated crops grown on the organic and sandy soils of Florida
Direct nutrient load measurements	Lack of acceptable methodology and effect of soil types makes current results spotty and difficult to extrapolate. Assumptions made on published load calculations are some times unrealistic or not met	Need a simple, reliable drainage lysimeter for on-farm monitoring Need to use lysimeter for direct assessment of BMP effect on water moving below the root zone and load
Zero discharge systems	Virtually none in field production. Good concept, but may be unrealistic in practice	Need to pursue ultra-low flow drip Need to pursue use of polyacrylamide and zeolite filters
Breeding and genetics	Virtually none in the context of BMPs	Need breeder's and administration's commitment Need to investigate morphological, biochemical and chemical strategies Need to use grafting
Nutrient sensors	Virtually all soil chemical information is based on soil sampling	Need specific NO_3-N, NH_4-N, P, and EC sensors that are inexpensive and reliable Data should be displayed through a user-friendly interface
Cover crops	Lots of information about effect on soil physical and chemical properties. Limited information on actual load reductions caused by nutrient trapping	Need reliable seed source and on-farm demonstration Need to assess long-term effect of cover crop use on nutrient load

Table 3. Questions to and summary of vision statements by key UF/IFAS state and county faculty with active programs in BMPs for vegetable crops

Question	Answers	Comments
1. What is your opinion/vision for the next 5 years on what the vegetable industry needs to do to improve their irrigation management?	Use recycled water	Note "recycled" rather than "reclaimed" Applies to drip and seepage irrigation
	Improve irrigation scheduling at the beginning and throughout the season	
	Routinely use soil moisture measuring devices (drip) or water-table indicators (seep)	Emphasis should be placed on reliability, cost, and simplicity of data collection and retrieval
	Consider and initiate a switch from seepage to drip irrigation	Mixed systems (seepage + drip) may be transition step
	Consider buried drip	
	Increase the precision of overhead (pivot) irrigation	
	Become more familiar with the capacity and function of existing drip systems	
2. What is your opinion/vision for the next 5 years on what the industry need to do to improve their fertilizer management?	Recalculate break even cost for fertilizers	
	Improve irrigation scheduling methods	
	Use tissue, sap test, SPAD readings or other spectral method as a monitoring tool	
	Integrate leguminous cover crops in production system and/or N trap crops after the production season	
	Apply less fertilizer more often (drip)	
	Use nutrient-efficient cultivars	
	Move to season-irrigation system-soil type specific nutrient recommendations (especially for N)	This was recommended by the UF/IFAS Vegetable Fertilizer Task Force*
	Increase industry confidence in UF/IFAS recommendations through regular updates and on-farm demonstrations	This was recommended by the UF/IFAS Vegetable Fertilizer Task Force*
	For crops like strawberry, N recommendations should be based on vegetative growth	This was recommended by the UF/IFAS Vegetable Fertilizer Task Force*
3. What educational programs are needed? (need to be separated for agents, for growers)	Hands-on workshops on nutrient/irrigation management for small farmers and middle-management/foreman level for large growers	Similar workshops have been locally offered in Homestead, Immokalee, TCAA, and NFREC-SV. "Basic" and "advanced" levels are needed. Fertilizer management advice relevant in other parts of the country may not apply to Florida
	Continue the face-to-face work of the BMP implementation teams	
	Support the one-on-one work of the MIL to all vegetable farms that use drip and seepage irrigation.	
	Support educational role of the BMP Implementation Teams	
	Cover crop management	
	Myth-breakers on some inaccurate "common wisdoms" on fertilizer management	
	Spray equipment and fertilizer injection calibration	
4. What are the critical issues on the horizon (5 to 10 years) that may affect the industry?	Food safety-related liability	
	Increasing cost of energy and reduced profit margins	
	Increased cost of fertilizers	
	Increased cost of food safety compliance	
	Loss of methyl bromide	
	Reduction in water permitted may require switching to drip, use ultra-low flow and recycled water	
	"Distractions" caused by food safety, labor, land availability and reduced state funding may push water quality efforts and compliance to "the back burner"	
	Maintain IFAS relevance to the industry	
5. Other	Restrict the use of Mehlich 1 soil test to soils with pH<7.2 and use another soil test when pH>7.2	
	Consider greenhouse or high tunnel as an alternative to field production	

* The recommendation was approved by the Plant Nutrient Oversight Committee

Table 4. Strategic areas of future research for improving the quality of Florida waters, their respective approaches and estimated chances of success.

Approach used to improve water quality	Possible areas of research	Estimated relative chance of success	Why?
Increase soil water holding capacity	Organic soil amendments	Low	Cost
Increase soil water holding capacity	Inorganic soil amendments	Low	Cost
Filter water at key points	Polyacrylamide blocks	High, short term	Technology already in use for water treatment for P and NH_4
Improve plant nutrient uptake efficiency: better root systems	Breeding and genetics	High, long term	Lack of emphasis from breeders, cost. Indirect link with water quality improvement
Improve plant nutrient uptake efficiency: synchronizing the expression of genetic progress in root and shoot	Grafting	High, short and long term	Grafting is a tool, not an end for pest management Could be used with breeding efforts with high-NUE rootstocks