Effectiveness of Tomato and Watermelon Water and Nutrient BMPs

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Background

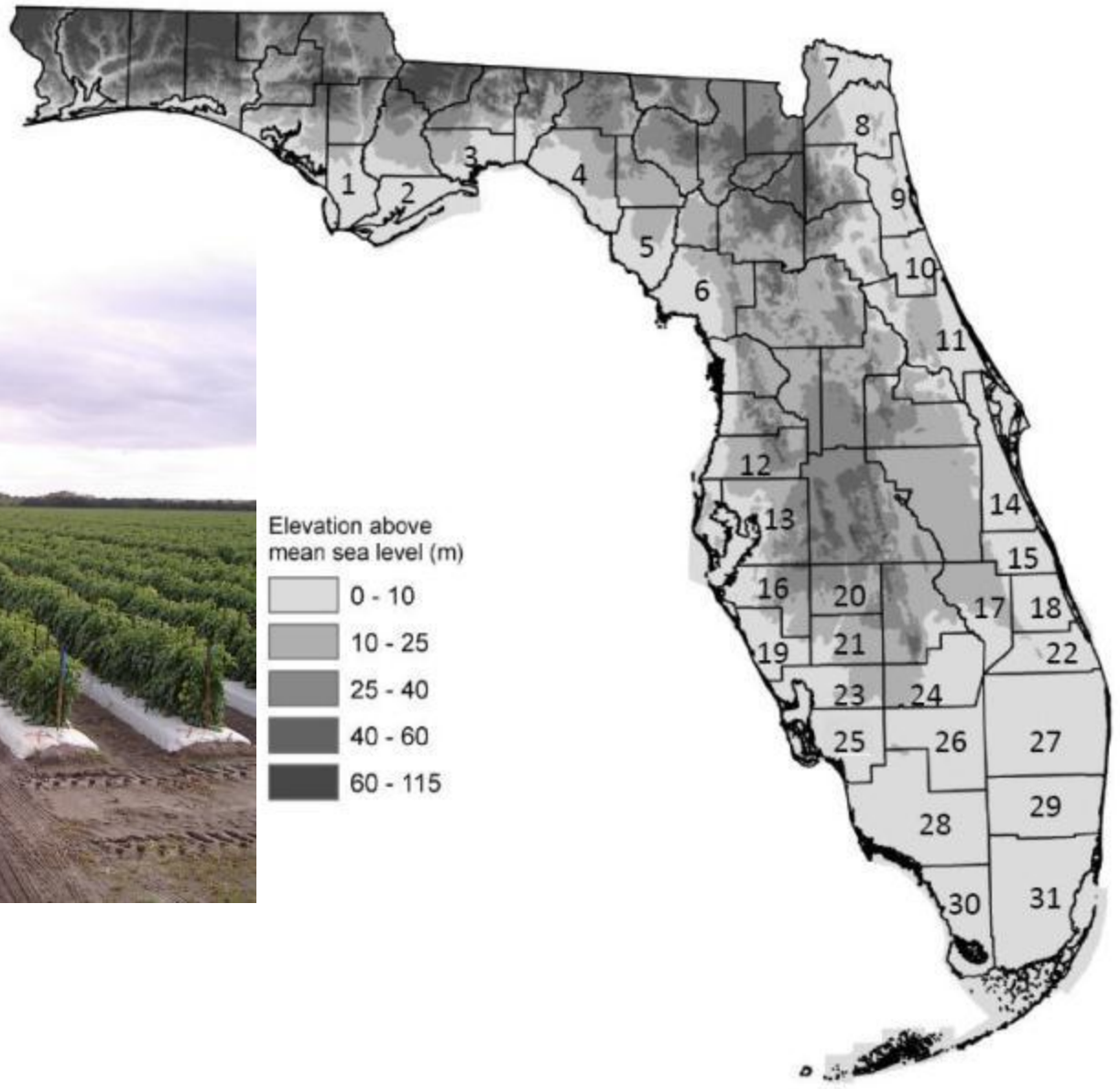
- Federal Clean Water Act (FCWA),1972
- Total Maximum Daily Loads (TMDLs)
  - Best Management Practices (BMPs)
- FDACS Vegetable and Row Crop BMP Manual
- Numerous BMPs listed but few have been verified
- Irrigation and nutrient management BMPs
  - Soil moisture based irrigation
  - Using recommended fertilizer
- Majority of tomato and watermelon growers in south Florida growers use seepage irrigation
- Need to evaluate the irrigation and nutrient BMPs

Best Management Practices (BMP)

"BMPs are a practice or combination of practices determined by the coordinating agencies, based on research, field-testing, and expert review, to be the most effective and **practicable** on-location means, including **economic and technological** considerations, for **improving water quality** in agricultural and urban discharges."

Florida Department of Agriculture and Consumer Services (FDACS)

Seepage Irrigation



Majority of South Florida Vegetable Crop Produced with Seepage Irrigation

Typical Studies Related to BMP

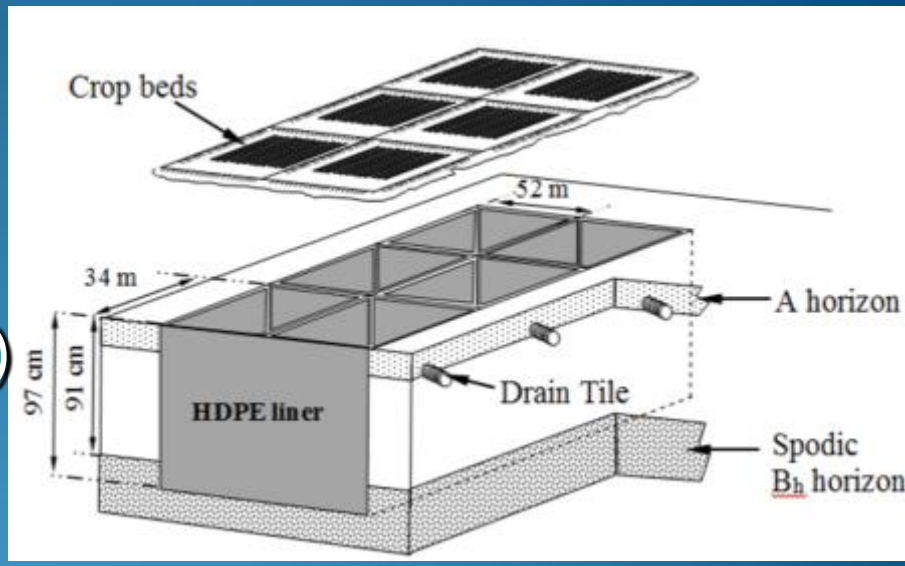
- Typical BMP studies
  - Evaluate crop yield **or** water quality,
  - Conducted on small scale plots
  - Confounding water quality effects due to groundwater mixing
- Lack of **Systems Approach**
  - Yield
  - Water use and quality
  - Economics

Objective

Evaluate the effectiveness of irrigation and nutrient BMPs for seepage irrigated tomato-watermelon production system for yield, water use, water quality, and farm income

Study Design

- Three year - SWFREC Immokalee, (2004-2006)



- Field Area – 3.6 acres
  - Six 0.6 ac fields
- Crops
  - Watermelon (2 Spring seasons)
  - Tomato (4 seasons)
- Hydrologically Isolated plots

- Three treatments:
  - Industry fertilizer-water input (High Rate, HR) - Grower Survey
  - BMP fertilizer-water input (BMP Recommended Rate, RR)
  - BMP input with sub-surface drip (RR-SD) - **Survey**

Irrigation and Nutrient Treatments

	Watermelon			Tomato		
Treatment	N lb/ac	P2O5 lb/ac	K2O lb/ac	N lb/ac	P2O5 lb/ac	K2O lb/ac
HR	265	170	459	373	162	673
RR & RR-SD	150	Soil Test	Soil Test	200	Soil Test	Soil Tests

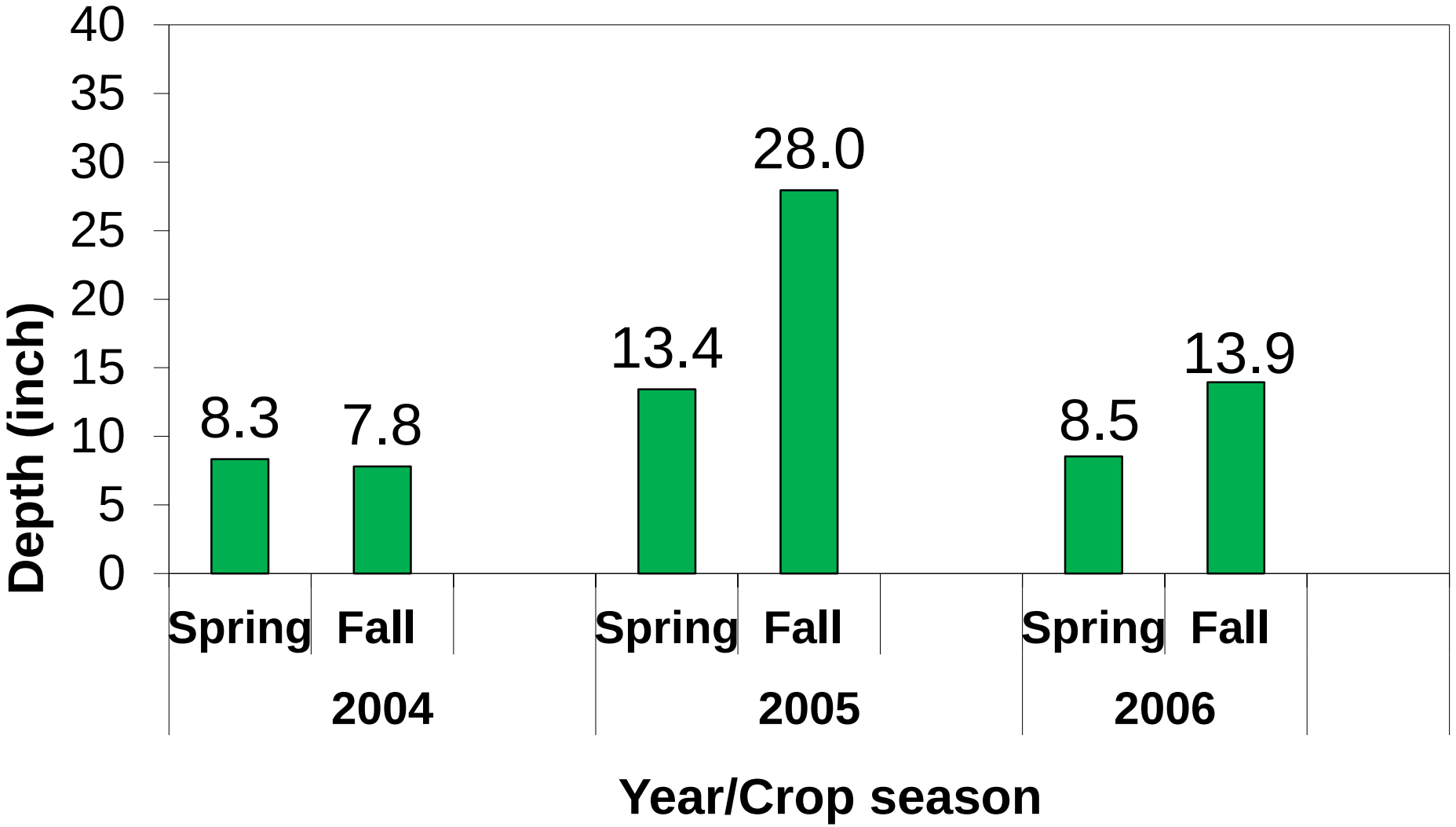
HR Water Management – 18% soil moisture content from surveyed farms
HR based on vegetable grower survey in South Florida (Shukla et al. 2004)

Measurements

- Fruit yield
  - 2- 3 harvests
- Plant nutrients (N and P)
  - Leaf tissue
  - Whole plant
- Hydrology
  - Water use
  - Soil moisture
  - Water table depth
- Soil and Water quality (NO_3, TN, TP)
  - Soil (0-10,10-20,20-30,30-40 cm)
  - Shallow and deep groundwater (N and P)

Results

Rainfall



- **Average annual rainfall ≈ 54 inch**
- **Rainfall from Hurricane Wilma (October 24th 2005) ≈ 8 inch.**

Yield

Tomato Yield

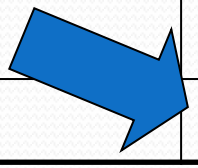
	Treatment	Yield (box/ac)
Fall 2004		
	HR	1,885
	RR	1,815
	RR-SD	1,946
Fall 2005		
	HR	659
	RR	853
	RR-SD	849

	Treatment	Yield (box/ac)
Spring 2006		
	HR	3,224
	RR	2,635
	RR-SD	2,592
Fall 2006		
	HR	2,449
	RR	2,089
	RR-SD	2,088

No statistical difference detected

Watermelon Yield

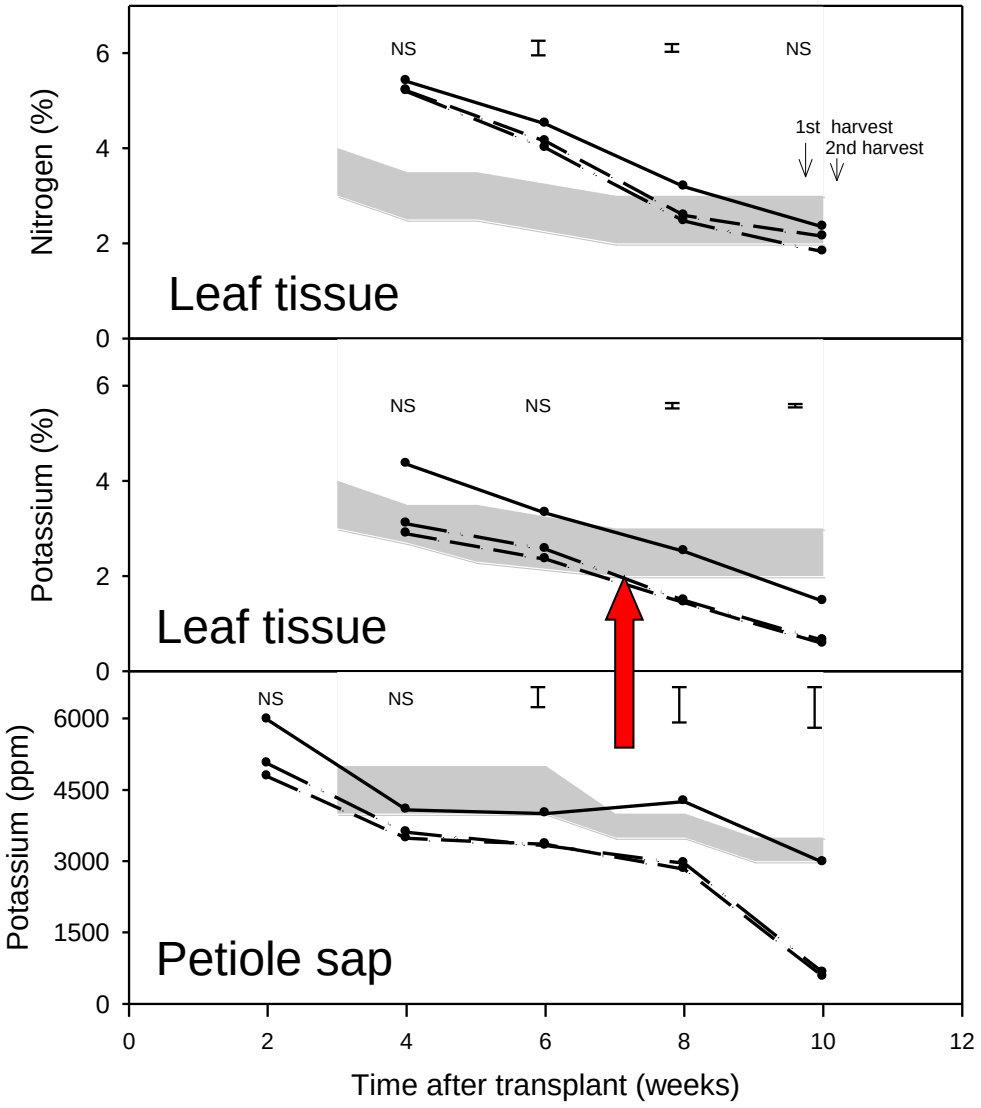
Year	Treatment	Yield	
		Diploid (cwt/ac)	Triploid (cwt/ac)
2004	HR	758a	444a
	RR	538a	261a
	RR-SD	475a	349a
Significance			
	P-value	0.261	0.336
2005	HR	--	345a
	RR	--	193b
	RR-SD	--	214b
Significance			
	P-value	--	0.031



Treatment effect detected for yield during 2005

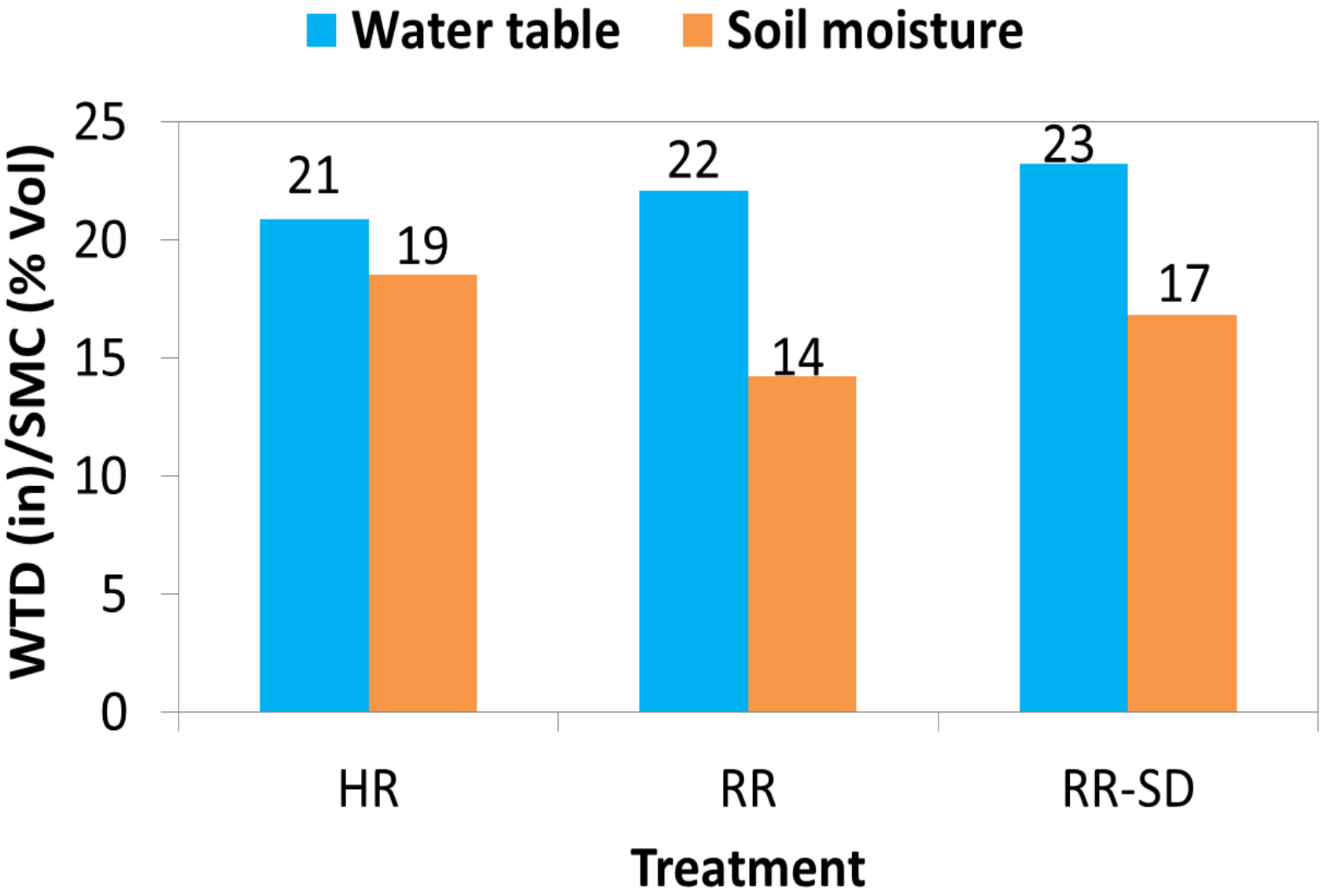
Watermelon

Tissue and Petiole Sap – Spring 2005

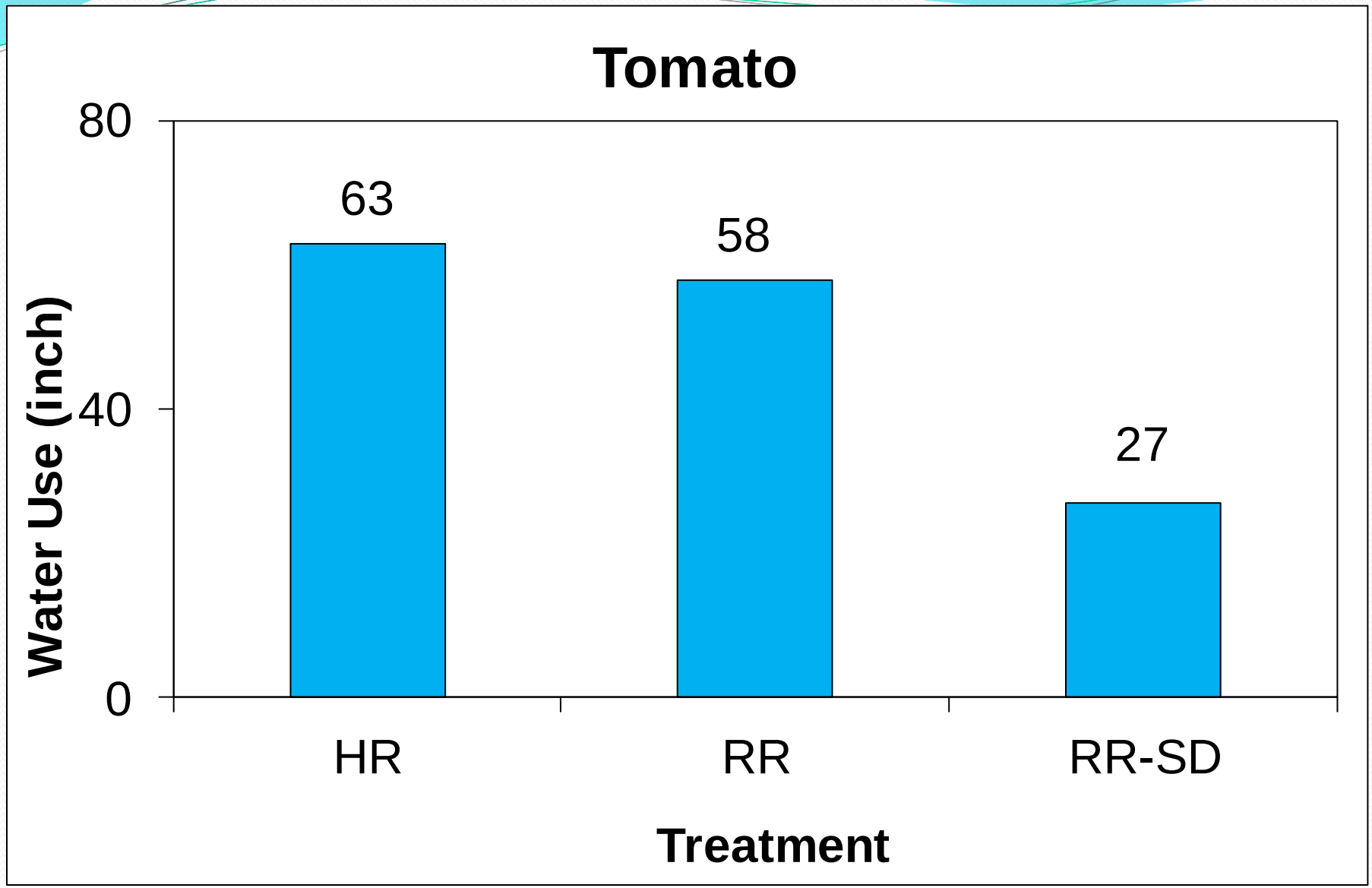


Leaching rainfall event: 3 in. over 3 days or 4 in. over 7 days

Water Table Depth and Soil Moisture



Average Water Use



System: HR – 74 in, RR – 68 in, RR-SD – 37 in

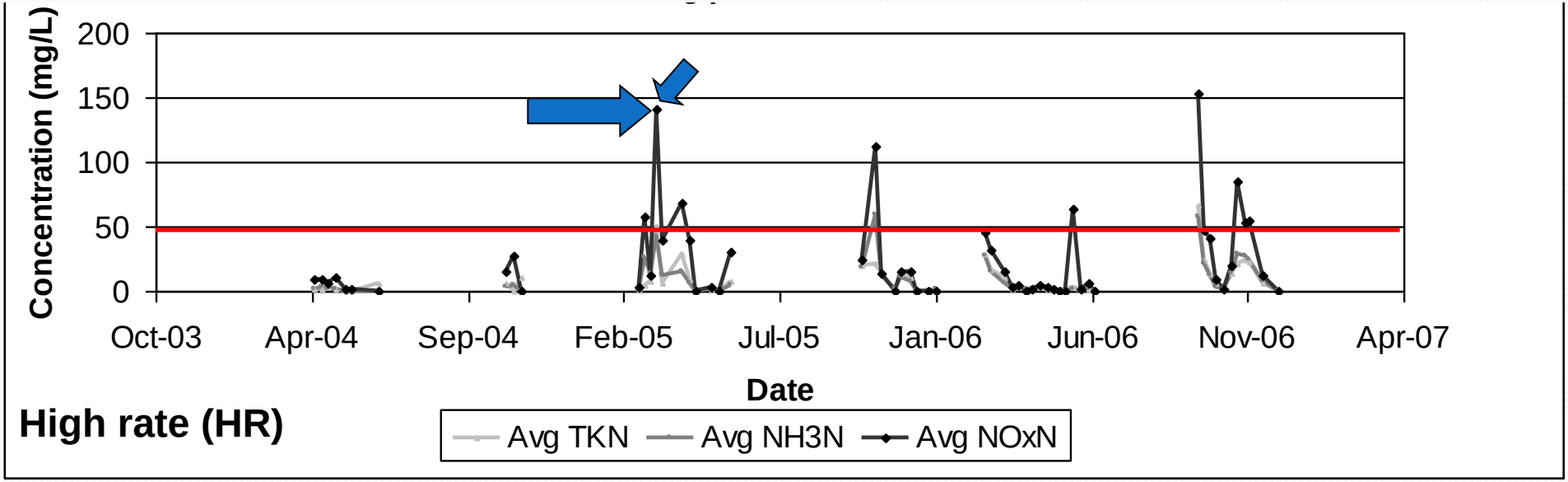
Soil and Groundwater Quality

Soil N (Tomato)

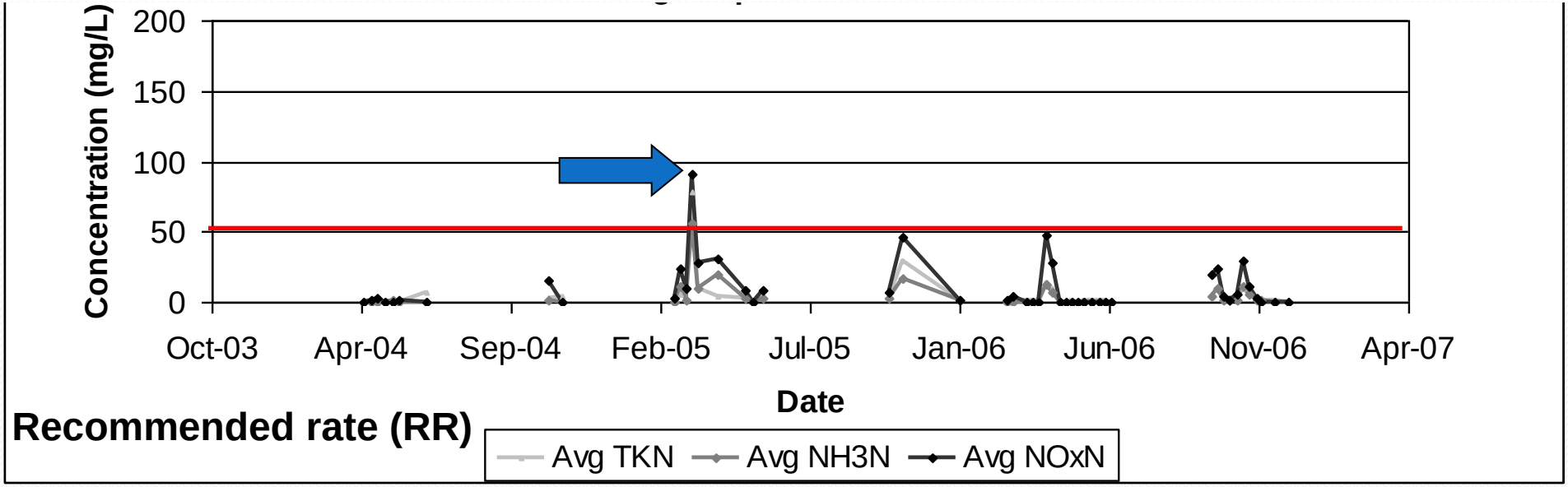
Nutrient	Treatment & Significance	Root Zone (0-8 in)	Below Root Zone (8-16 in)
NO_3-N (mg/kg)	HR	121	23
	RR	63	14
	P - value	< 0.05	0.07
TN (mg/kg)	HR	519	269
	RR	363	230
	P - value	< 0.05	0.22

Treatment effect ($P<0.05$) occurred mostly within the crop bed

Groundwater N

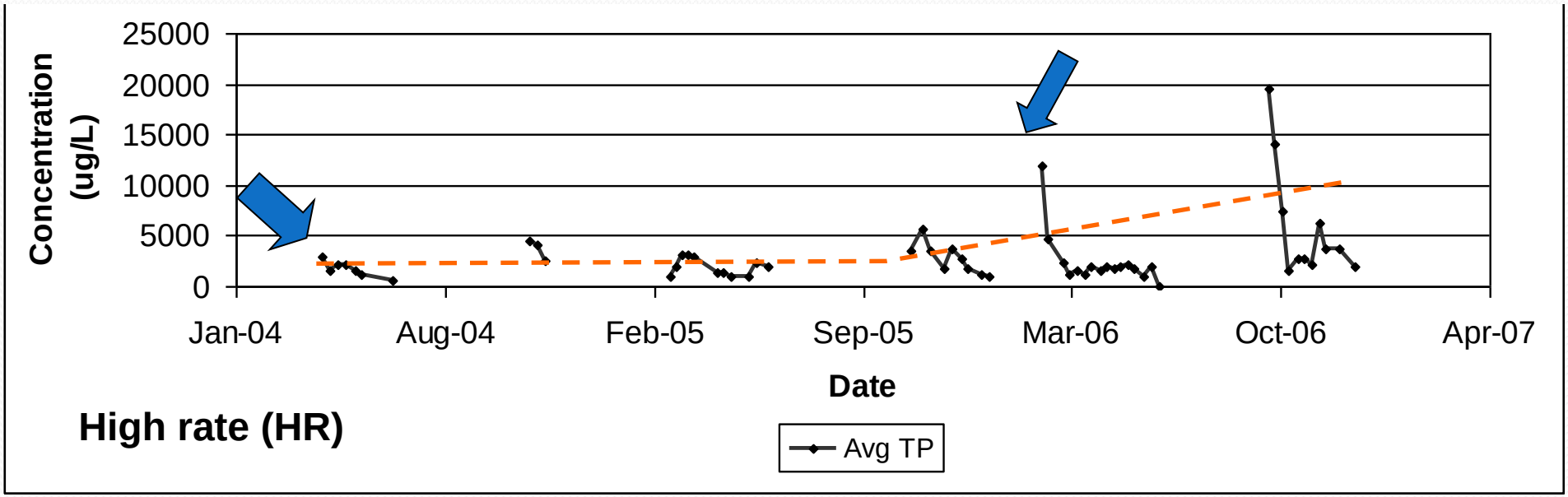


High rate (HR)

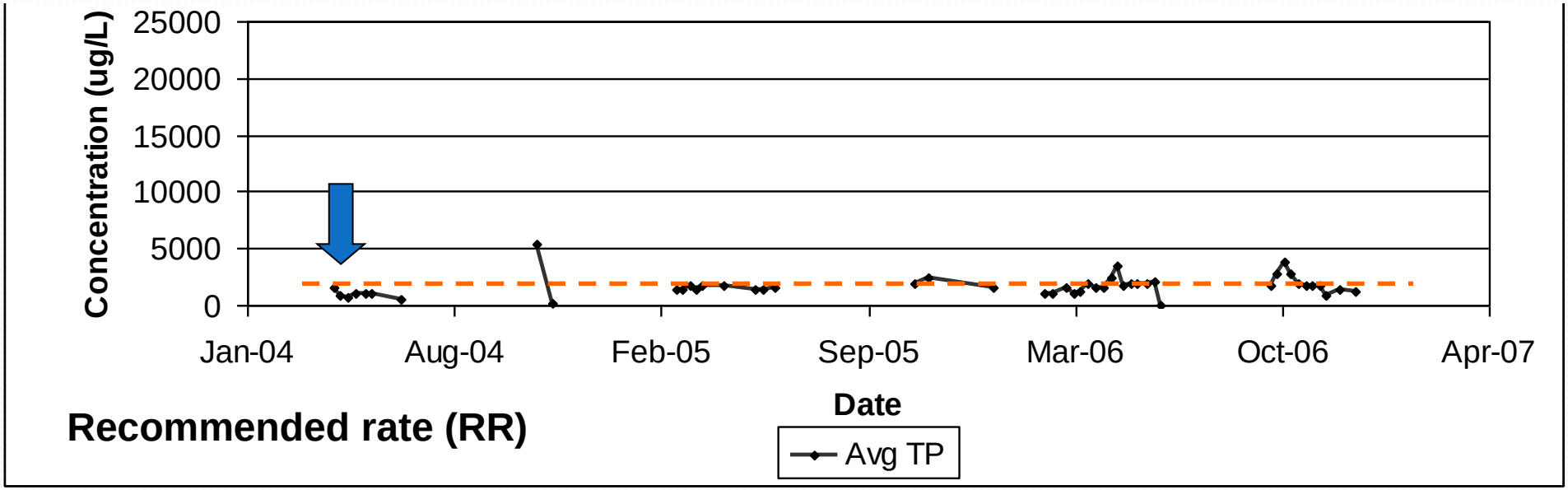


Recommended rate (RR)

Groundwater Total P

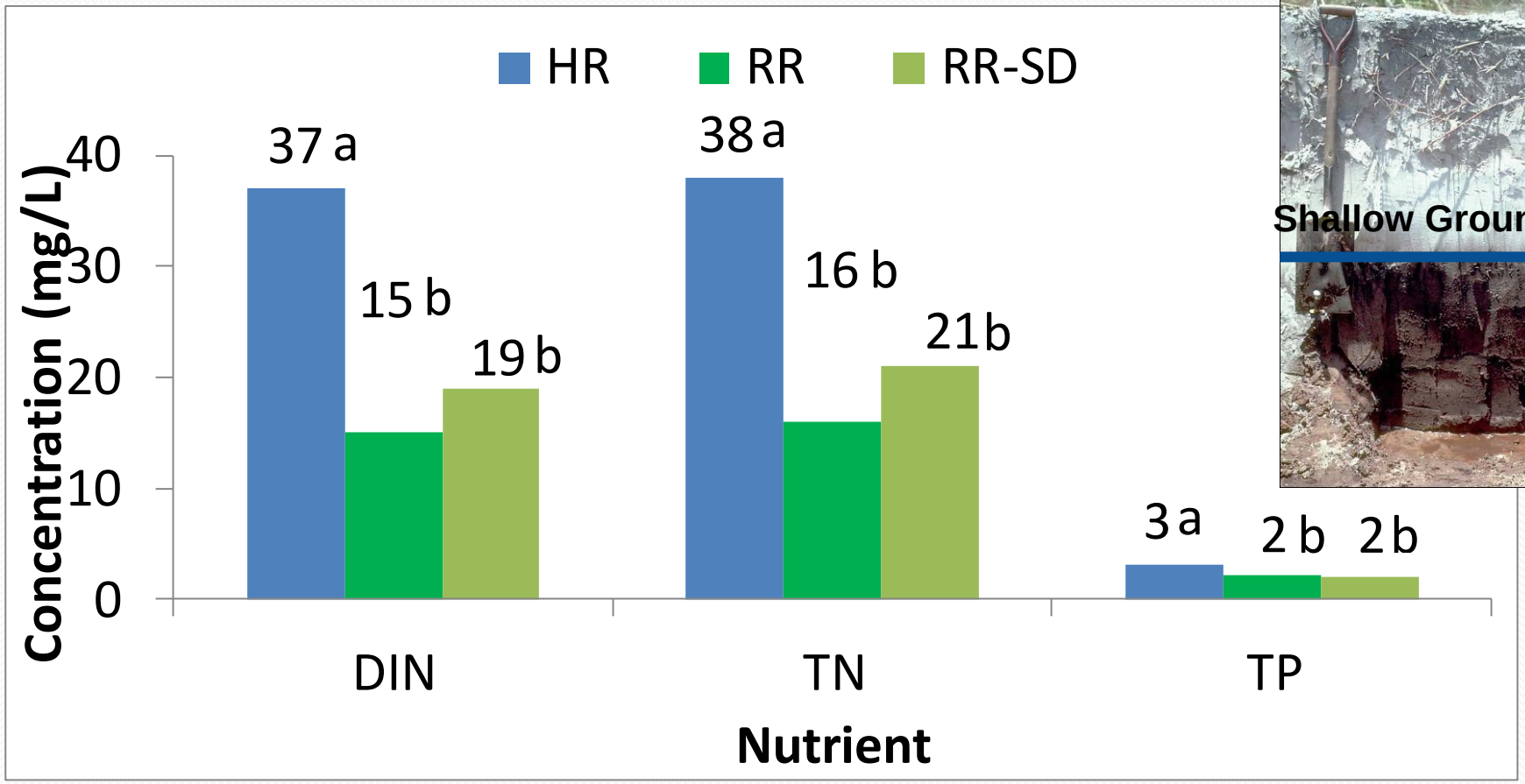


High rate (HR)



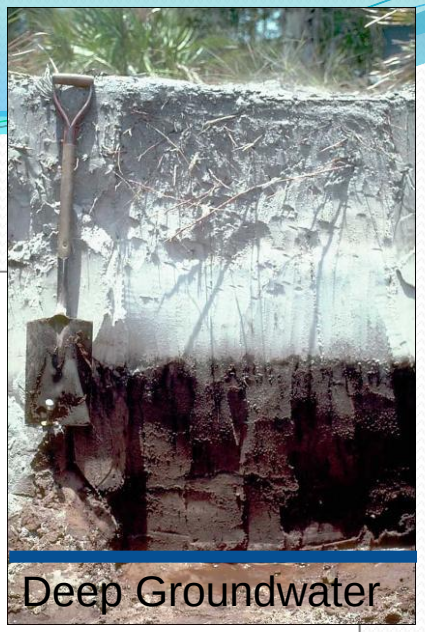
Recommended rate (RR)

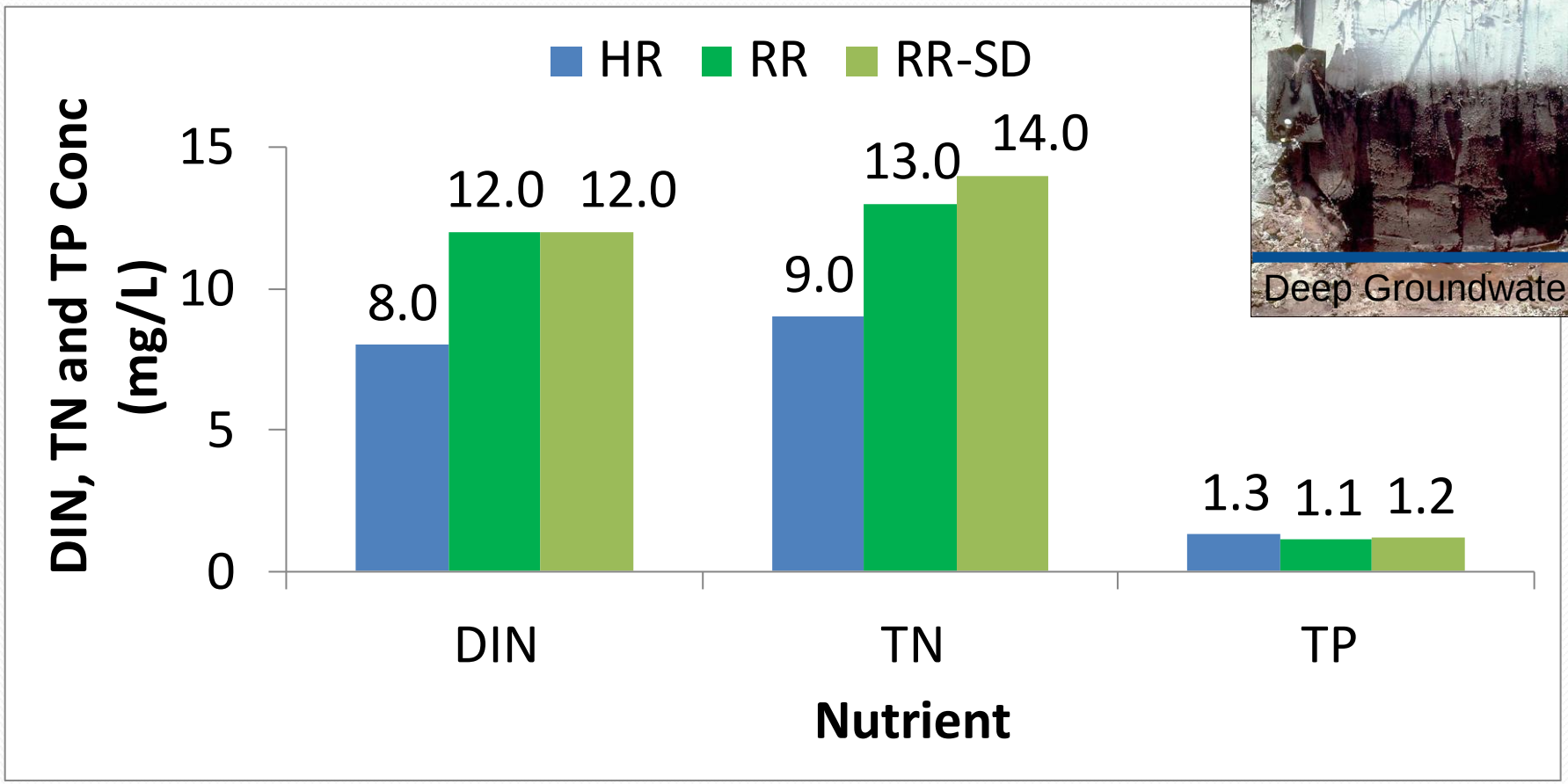
Shallow Groundwater N and P



Treatment effect detected (P< 0.05) for shallow groundwater N and P

Deep Groundwater N and P





No treatment effect detected ($P < 0.05$) for deep groundwater N and P

So is RR a BMP?

Long-term study

Summary

- No statistical difference in tomato yield between Industry and BMP
- Under “average” rainfall conditions, no statistical difference in watermelon yield between Industry and BMP
- Wetter conditions during the spring season may reduce the watermelon yield. Further research is needed to develop nutrient management strategies (especially K) for wetter conditions.

Summary

- The BMPs reduced the total N and P concentrations in groundwater by 50 and 33%, respectively compared to the Industry.
- The BMPs reduced the water use by 7 % (seepage, RR) and 50% (sub-drip, RR-SD)
- Long-term studies needed to detect the differences in tomato yield, if present.
- Reduced N and P leaching to the groundwater found in this study is likely to reduce the N and P loads.
- First study to quantify yield, economic, and water quality effects of BMPs, more needed

Acknowledgements

Southwest Florida Vegetable Growers Research Fund

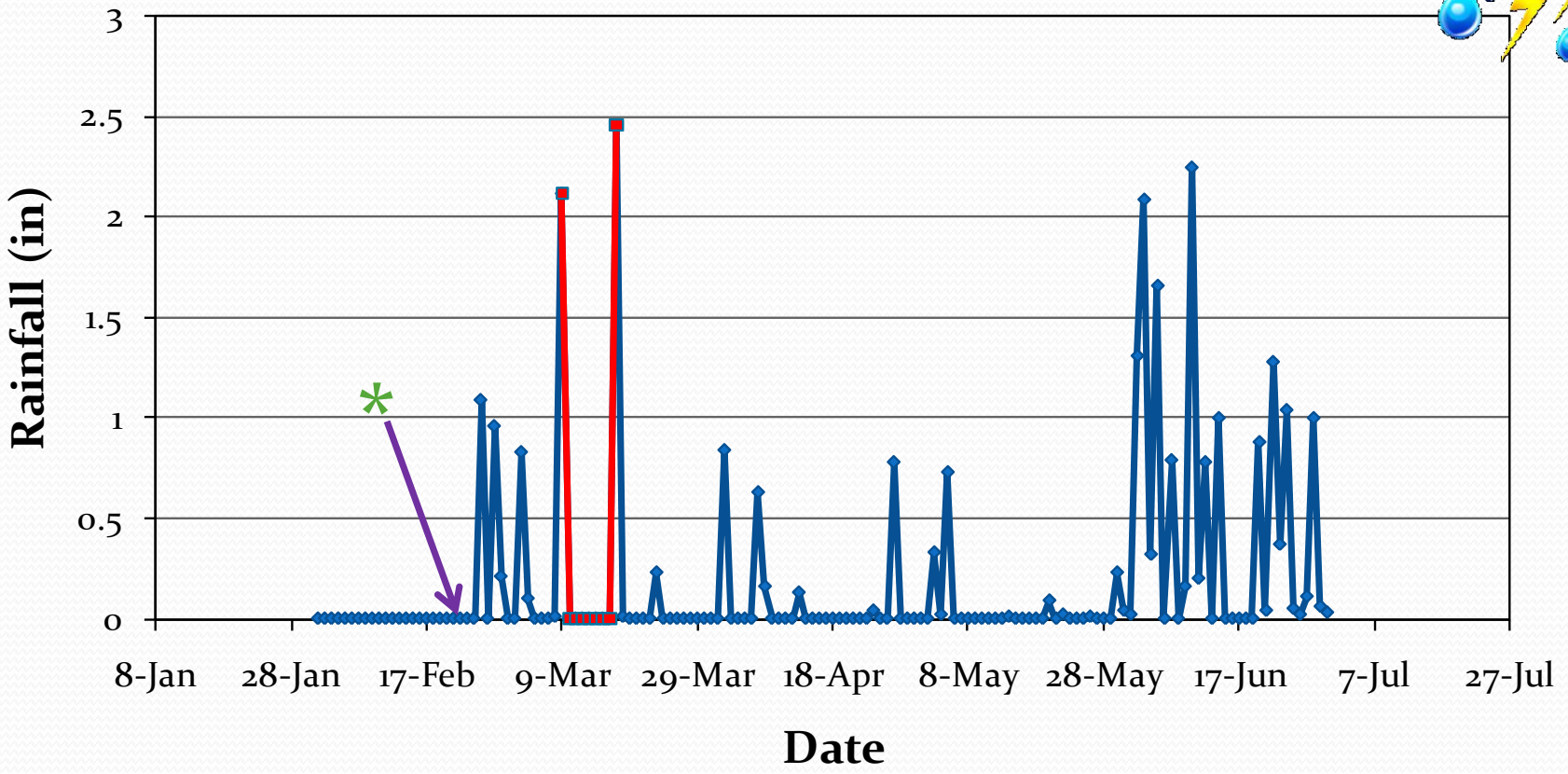
Vegetable Growers

Florida Department of Agriculture and Consumer Services

Fresh from Florida

Southwest Florida Water Management District

Rainfall-Spring 2005



*Beds preparation and transplant-2/21/05

Seasonal average = 11.1 in.

Rainfall during spring 2005 (18.2 in) was 3 times greater than spring 2004 (5.4 in)

Summary

- No yield differences for tomato yield
- No yield differences for watermelon produced under average weather conditions
- N-Leaching higher and more frequent in the HR treatment
- Higher concentrations of groundwater N and P are maintained above the spodic layer of the HR treatment
- No treatment effect detected in groundwater N and P below the spodic layer

Conclusions

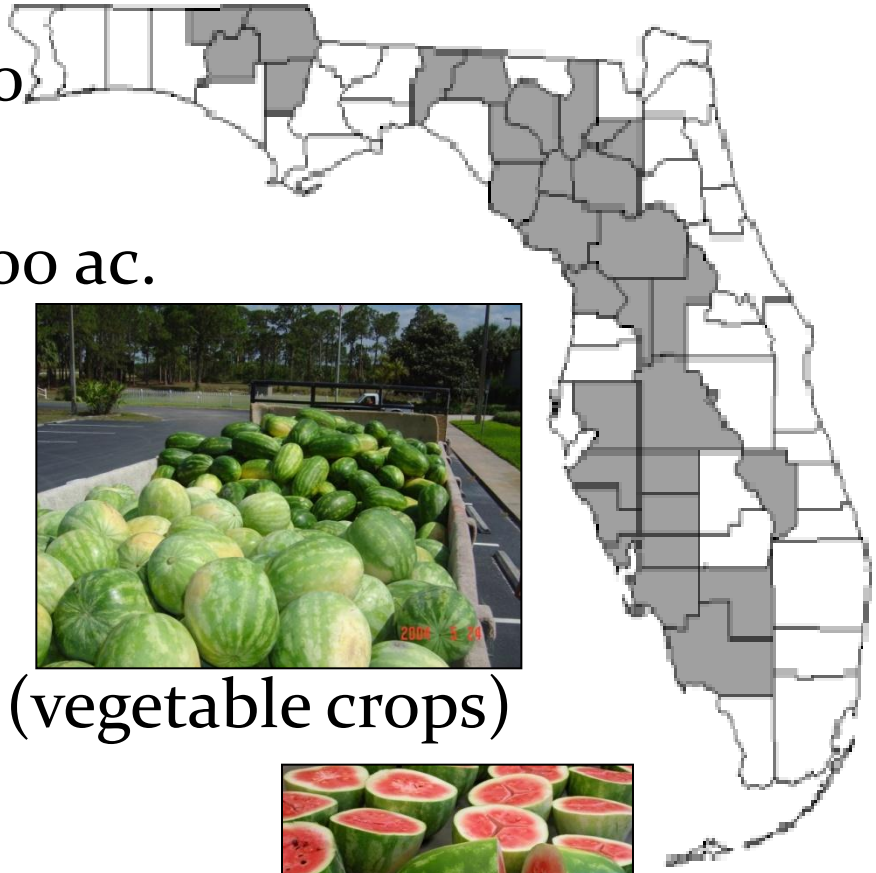
- RR-SD treatment reduced water use by more the 50% compared to HR and RR treatments
- RR and RR-SD treatments is a BMP under average weather conditions
- First ever study to show a link between recommended fertilizer-water inputs and improved groundwater quality with no effect on yield

Study Implications

- First ever study to show a link between recommended fertilizer-water inputs and improved groundwater quality with no effect on yield.
- Growers maybe more receptive in accepting and adopting recommended fertilizer-water inputs for vegetable production in south west Florida.

Background

- Cash value* – $140,392,000
- Yield* – 330 cwt/ac.
- Harvested acreage* – 26,100 ac.
- Plastic mulched beds
- Crop rotation
  - Watermelon-Spring
  - Tomato or pepper-Fall
- Florida irrigation systems (vegetable crops)
  - Sprinkler(69,951 ac.)†
  - Micro (21,025 ac.)†
  - Flood (118,949 ac.)†



* (USDA, 2008),†(Marella, 2004)

Image source: IPM center (www.ipmcenters.org)

Drip vs. Seepage Irrigation

Drip

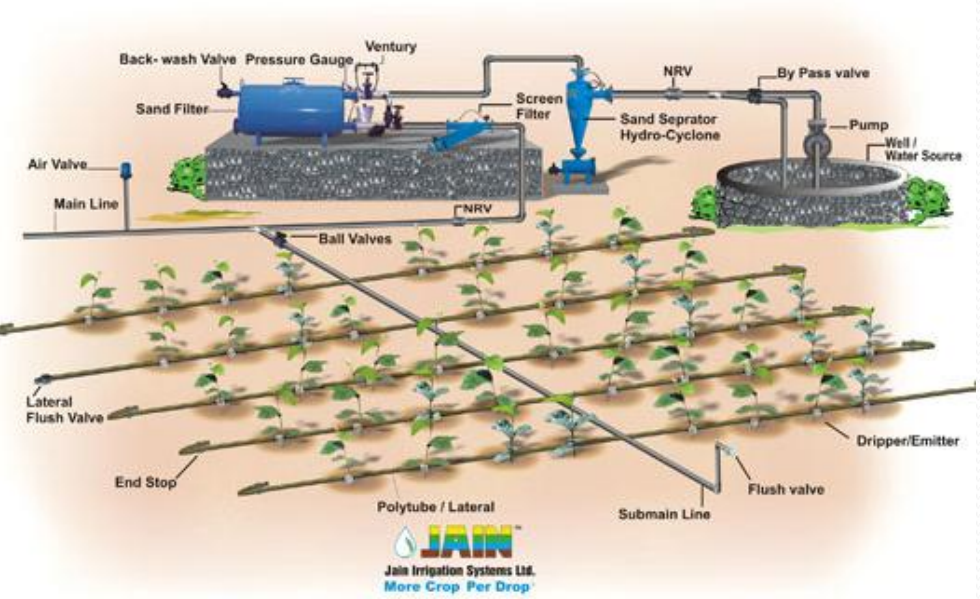


Image source: www.jains.com/irrigation

- Water and fertilizer (Can apply as needed)

Seepage

- Water (All fertilizer -pre-plant)

Recommended BMPs

- Nutrient management
  - Optimum N rates
  - Soil test based P and K applications
  - Supplemental (N and K)
    - Hand/Liquid fertilizer injection wheel
    - Extended harvest season
    - Open field leaching Rainfall-3" in 3 days, 4" in 7 days
- Water management
  - Soil moisture-based (Seepage and Drip)
  - ET-based (Drip)

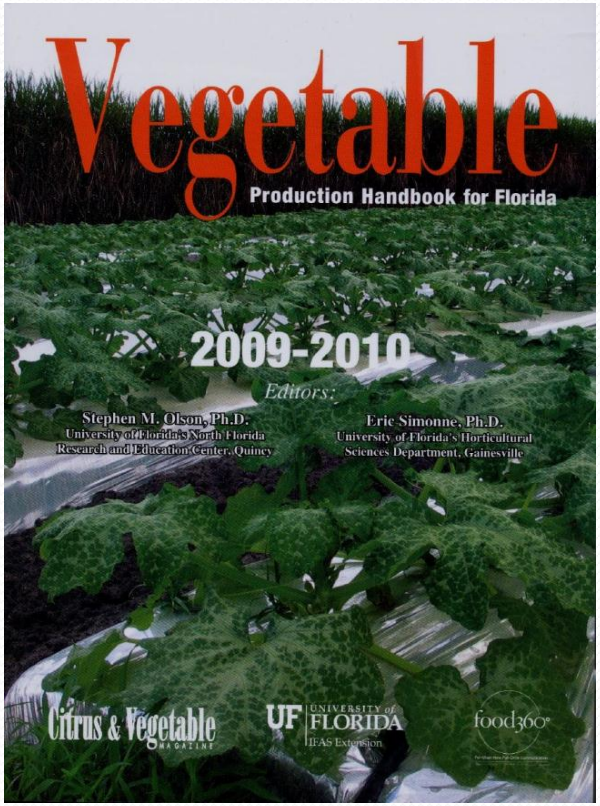


Image source: The Vegetarian Newsletter (www.hos.ufl.edu/vegetarian/)

Current Practice (grower survey)

- Nutrient Input
  - Likely greater than recommended
  - Applied as insurance to ensure max yield
    - Multiple harvests
    - Healthier plants
  - Limited use of soil test based P and K
- Water management
  - Moisture content above field capacity
  - Limited use of soil moisture or ET-based irrigation management

Image source: www.musicpodcasting.org/home/node/48

Watermelon Grower Survey

South Florida*	N (lbs/ac)	P_2O_5 (lbs/ac)	K_2O (lbs/ac)
Average	199 (150)	128 (120-L)	347 (120-L)
Min	138	83	220
Max	266	220	501

L = soil testing low nutrient, *(Shukla et. al., 2004)

- Growers apprehensive about nutrient recommendations
- Data needed to evaluate if water-nutrient BMPs work wrt yield and water quality
- Focus on a specific nutrient BMP may detract growers from other BMPs
- When a management practice becomes a **BMP**?

BMP Essentials

- Improve water quality in agricultural discharges
- Include economic and technological considerations

BMP Effectiveness study must address:

- Water quality
- Crop yield
- Farm economics

Watermelon-Tomato BMP Study*

- Watermelon-Tomato rotations
- Traditional cultural practices
- Grower average (HR) Vs. recommended (RR) nutrient-water rates
- Plots hydrologically separated- reduces uncertainty groundwater quality analysis.
- Crop yield and groundwater quality evaluated

(Shukla and Hendricks, 2009)

Results

- Yield Analysis
- Tissue Analysis
- Economic Analysis
- Groundwater Quality Analysis
- Water Use

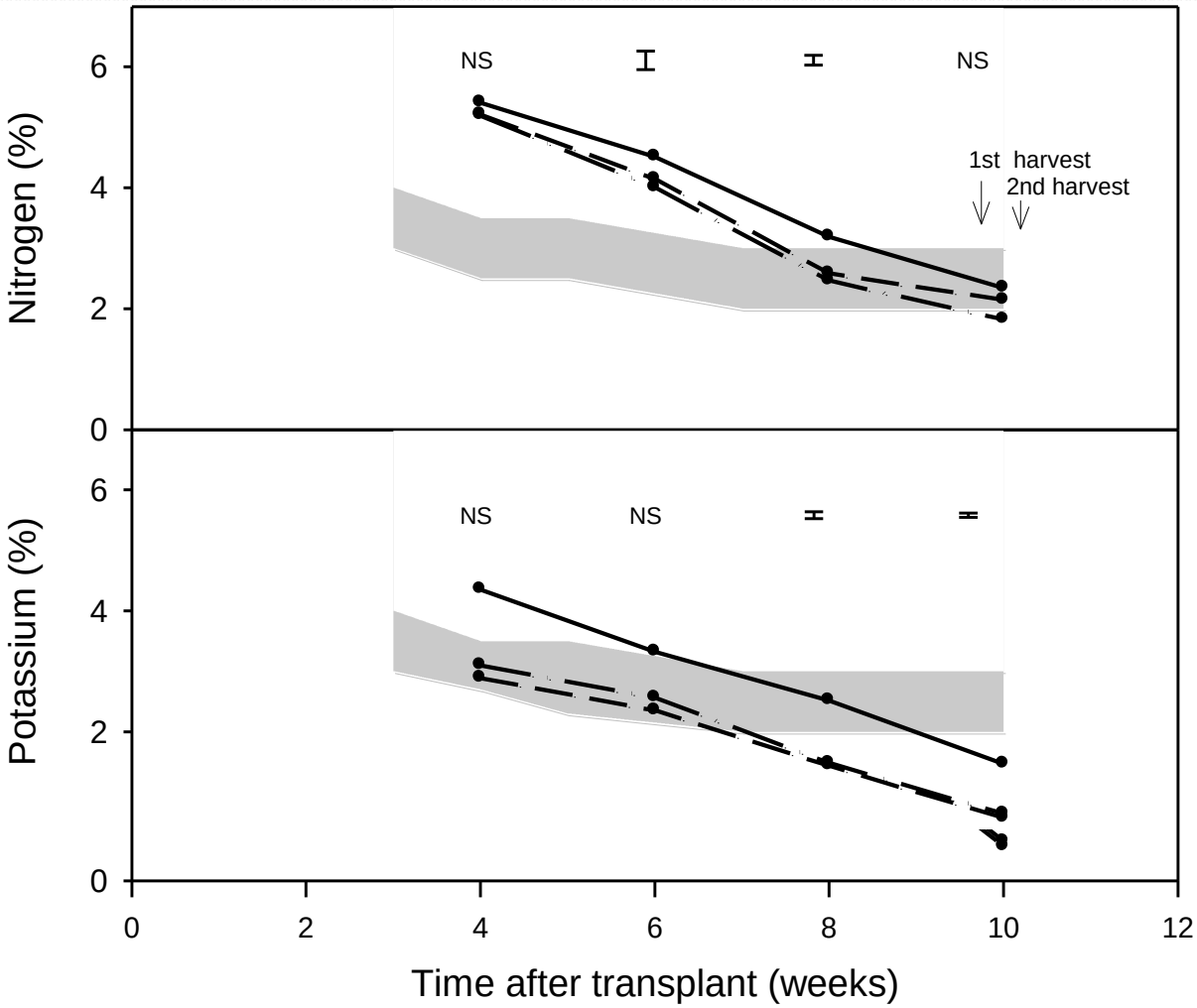
Source: infinitibusinesssolution.com

Watermelon Yield

Year	Treatment	Triploid Yield(cwt/ac.)
2004	HR	444
	RR	261
	RR-S	349
Significance		
	p	0.336
2005	HR	**345**
	RR	193
	RR-S	214
Significance		
	p	0.031

- Yield reduction occurred during 2005. Why?

Leaf Tissue Analysis



- Watermelon plants in RR treatments deficient in Potassium (and N?)
- Potassium deficiency likely due to leaching rainfall event
- Economic impact?

Solid line - Seepage

Dash lines- RR and RR-SD

Hendricks, Shukla, Cushman, Obreza. Roka, McAvoy, and Portier 2007

Economic Analysis (Year 2005)

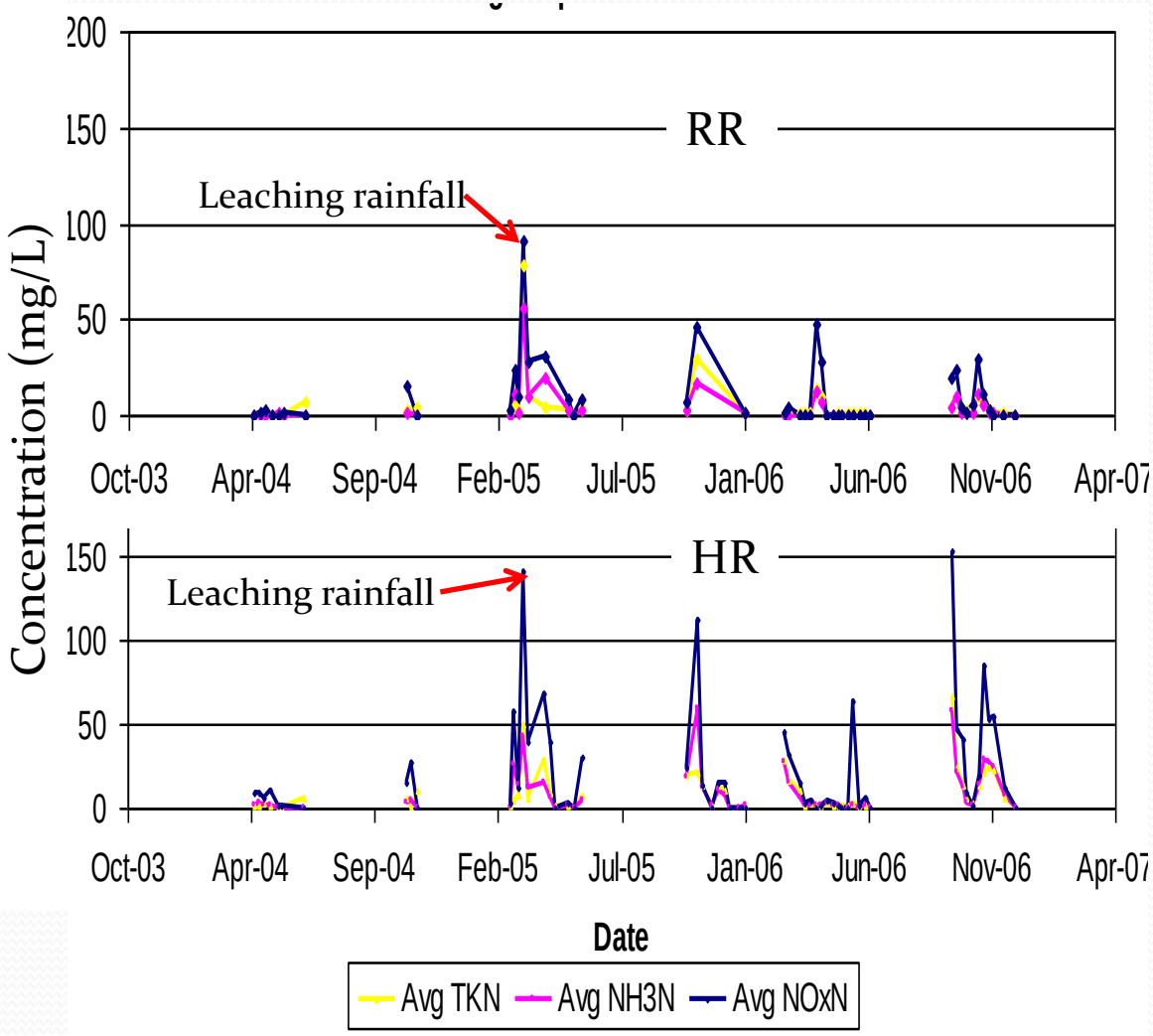
- Added yield from HR
  I. Low – 130 cwt/acre
  II. High – 150 cwt/acre
- Average season prices for triploids
  a. $8.40/cwt in 2004 to
  b. $15.50/cwt in 2005
- HR Return Gain (low yield gain and market price) = $590/acre
- HR Return Gain (high yield gain and market price) = $1764/acre

Environmental Impact?

Hendricks et al (2009)

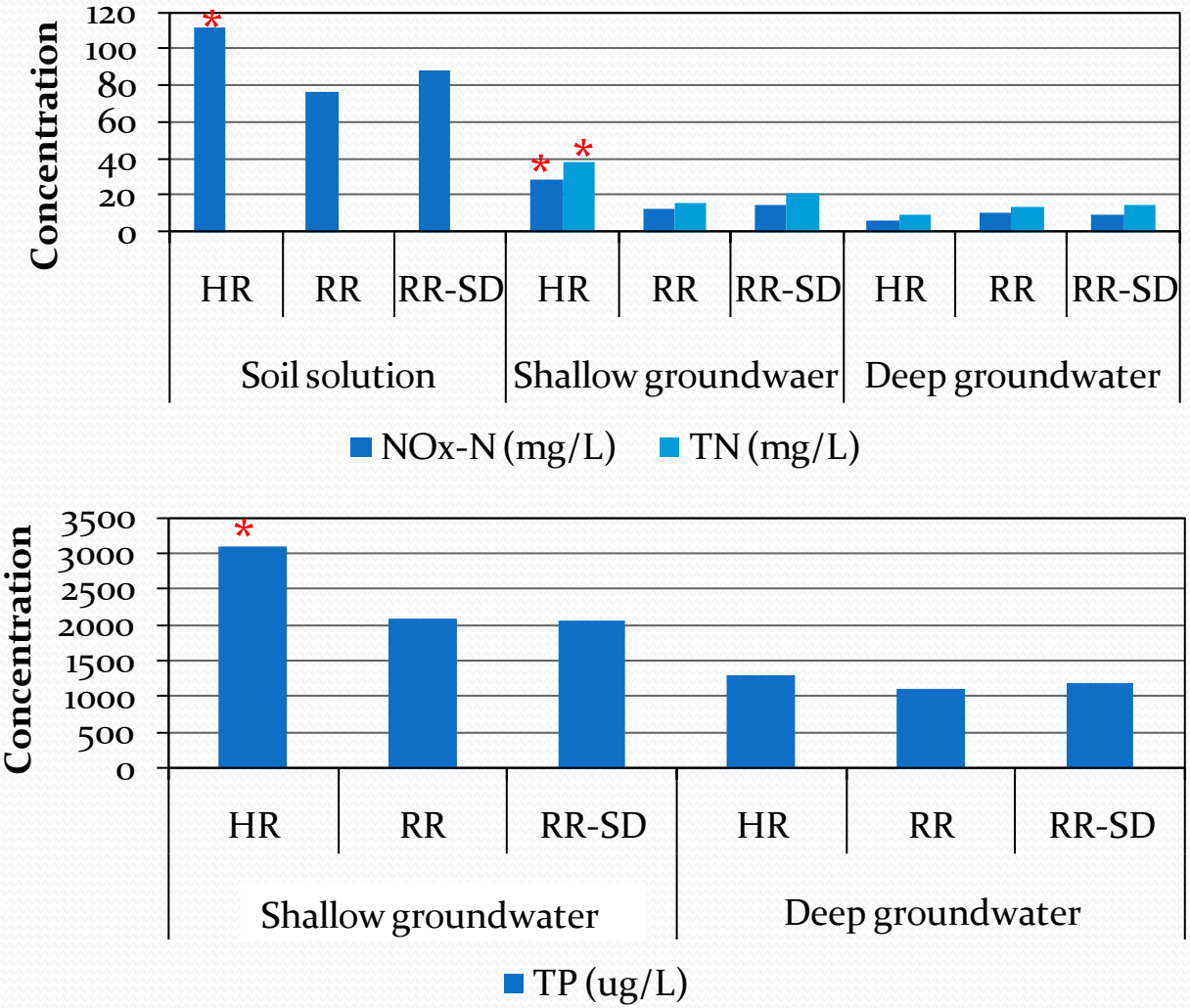
Groundwater Quality (N Conc^{n})

Avg TKN, NH_3-N and NOx-N within **RR and HR treatments**



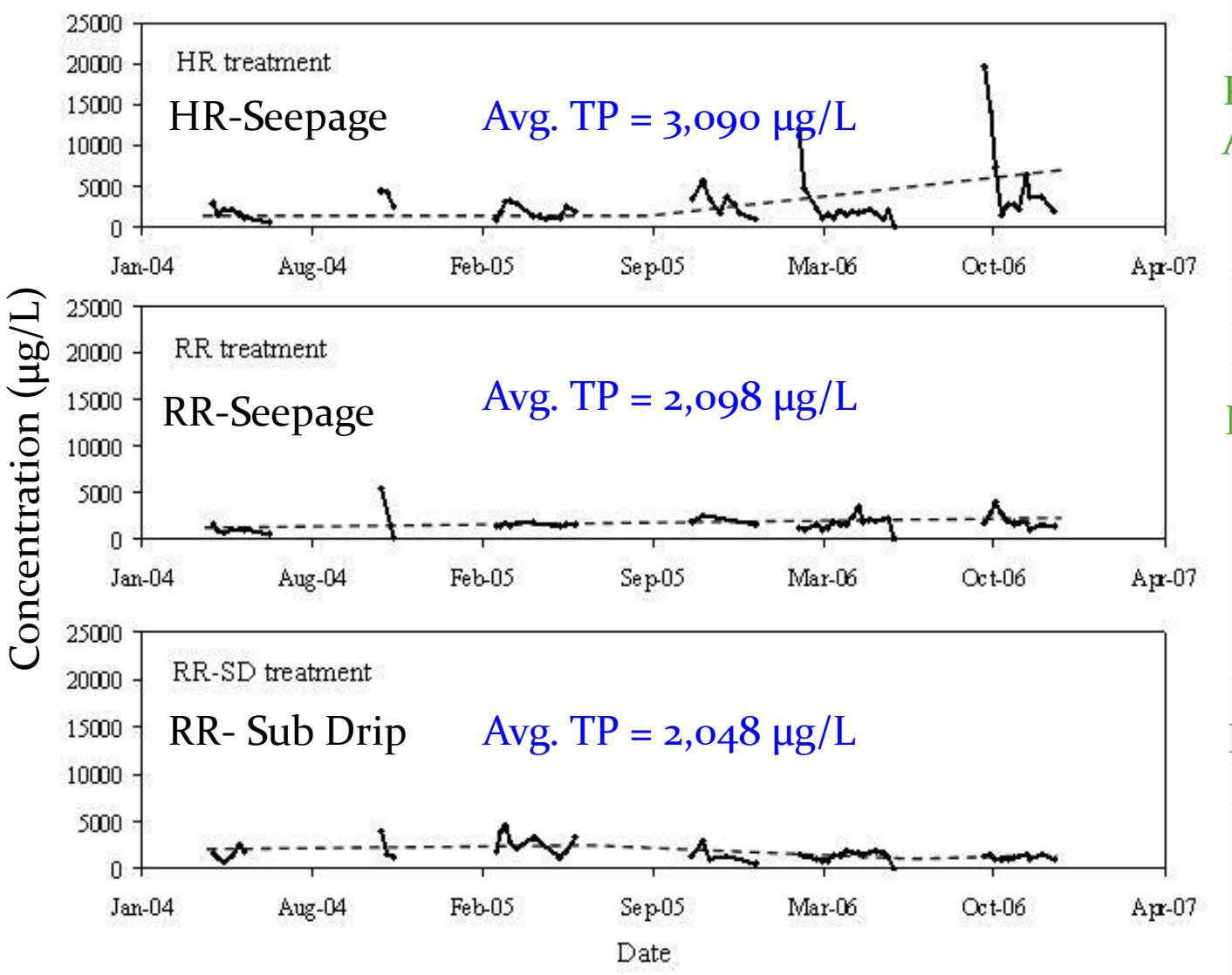
- Integrated systems approach used to analyze groundwater quality
- watermelon and tomato rotation

Soil and Groundwater Quality



- Soil Solution N Conc^{n} HR > RR and RR-SD
- Improved groundwater quality with RR and RR-SD
- Quality of deep groundwater unchanged

Shallow Groundwater P (above spodic)



Progressive Accumulation of P

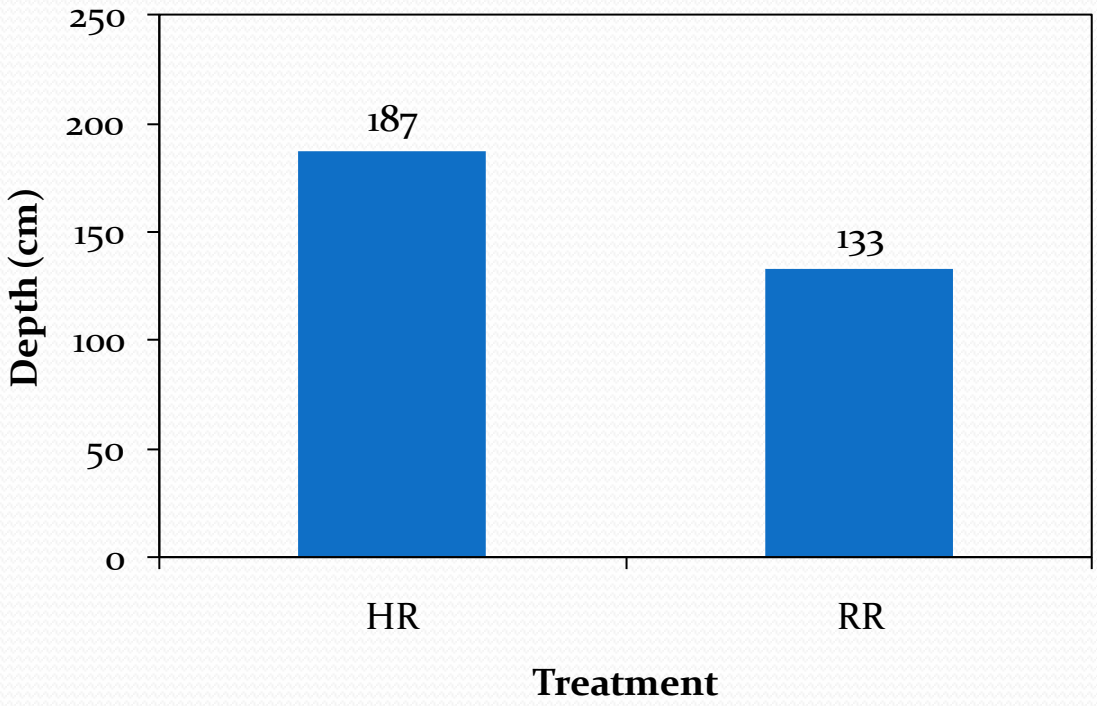
Relatively Stable P

Relatively Stable P

Average TP Conc. in HR 47% higher than average TP Conc. in RR

Water Use

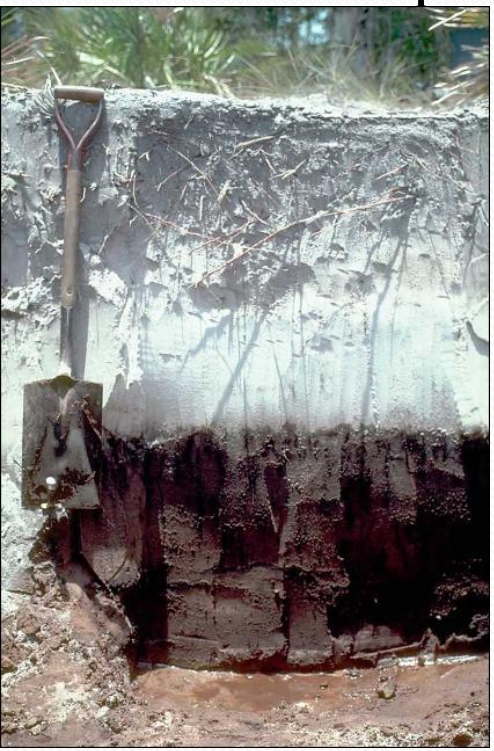
- Reduced average water use for RR and RR-SD compared to HR



So, was it a BMP?

Water-nutrient BMP status for watermelon Yield

- RRs worked under “average” weather conditions
- RRs reduced the yield and profit under “wet” conditions
- RRs improved water quality-groundwater (and surface water)



Drip Irrigation

- ET-based water management for watermelon
- Crop Coefficient (Kc)
  - 0-28 DAT – 0.57
  - 29-56 DAT – 0.89
  - 57-84 DAT – 0.76
    - Shukla et al (2008)

Future Research Issues

- The BMP evaluation study needs to be continued for more growing seasons to better evaluate BMP effectiveness under variable weather and economic condition
- Development of water table management tools
  - Water table vs rainfall relationship for active water table management for irrigation and drainage
  - Linking rainfall predictions with water and nutrient input

Future Research Issues

- Leaching rainfall
  - evaluation of supplemental fertilizer
  - frequent “normal” rainfall vs. “leaching rainfall”
    - water table change = 16 x rain (Jaber and Shukla, 2006)
- Comparison of drip and seepage production systems
  - water quality, yield, and economic
  - variable soil conditions
- Drip irrigation management
  - not managed properly, can have higher leaching than seepage
  - ET-based using recently developed Kc
  - water quality effectiveness
- How to minimize leaching after removing plastic
  - considerable N-P-K left after harvest

Measurements