

Evaluation of Water and Nutrient BMP's for Vegetable Production With Seepage Irrigation in Southwest Florida

June 20, 2007

Sanjay Shukla¹
Gregory Hendricks¹
James Knowles¹
Kent C Cushman²
Thomas A. Obreza³
Fritz M Roka⁴
Gene McAvoy⁵

Agricultural and Biological Engineering Department, Southwest Florida
Research and Education Center (SWFREC), Immokalee¹
Horticultural Science Department, SWFREC, Immokalee²
Soil and Water Science Department, Gainesville³
Food and Resource Economics Department, SWFREC, Immokalee⁴
Hendry County Extension, LaBelle⁵

Institute of Food and Agricultural Sciences (IFAS)
University of Florida
Immokalee, FL 34142

A Report to Meet the Requirements of the FDACS Contract #012158 (UF 00065741)

Report No. WRP-SP-05

Deliverable 5

Submitted to:

Florida Department of Agriculture and Consumer Services, Tallahassee, FL

Background

Southwest Florida produces a higher quantity of vegetables compared with other regions of Florida. One of the main vegetables produced in the region is tomatoes. The region is home to major tomato and watermelon producing counties of Florida, including Manatee and Hendry counties. Vegetable production on poorly-drained Southwest Florida soils requires careful management of water and nutrients to reduce off-site nutrient transport to surface and ground waters and to maintain profitable crop yields. Tomato and watermelon production involves the use of the seepage irrigation with raised beds and plastic mulch. Seepage irrigation involves raising the water table to provide moisture to the root zone via upflux. The water table is adjusted during the crop season to control moisture levels in the crop root zone. High water table conditions (e.g. 18 inches from the top of the bed) combined with rapid water movement in sandy soils in southern Florida can result in large fluctuations in water table levels in response to rainfall and irrigation. Water table fluctuations in seepage irrigation systems could result in a significant movement of fertilizer out of the root zone. Water table management has a direct and profound impact on soil moisture and nutrient concentrations in the root zone. Either wet or dry soil moisture conditions can adversely impact crop yield, but water management can also cause low or high nutrient concentrations in the root zone. Therefore, water and nutrients have to be managed simultaneously to optimize yield and minimize nutrient losses to groundwater.

Irrigation management practices used by growers vary from simple to complex. Some growers rely on experience and personal judgment to assess soil moisture for irrigation management. Other growers use sophisticated moisture monitoring devices and/or evapotranspiration data to schedule irrigation. Likewise, N, P and K applied to watermelon crops vary according to grower preference and site-specific conditions such as soil characteristics. According to a survey of southwestern Florida watermelon growers, the average N, P, and K rates were 265, 74, and 381 lb/acre, respectively (Shukla et al., 2004). Fertilizer recommendations developed by UF-IFAS for watermelon are 150 lb/acre N along with P and K application rates determined by soil testing and laboratory recommendations (Maynard et al., 2001). Recommendations for managing irrigation, although less specific than for fertilizer, include managing soil water between field capacity and 50% depletion of the plant available water to avoid plant water stress (Natural Resources Conservation Service, 1993).

Florida's vegetable industry is faced with environmental issues such as the development of total maximum daily load (TMDL) for nutrients of concern such as N and P. To achieve water quality goals, state agencies are promoting the use of best management practices (BMPs). BMPs are a practice or combination of practices based on research, field-testing, and expert review deemed to be effective and practicable for producers and for improving water quality in agricultural discharges (Florida Department of Agriculture and Consumer Services, 2005). BMPs are required to be economical and technologically feasible. To maximize yields, fertilizer and water inputs for watermelon production in southern Florida often exceed the recommended inputs. To promote the use of recommended inputs, current production practices need to be compared with the recommended practices with special emphasis on water quality impacts, yield performance and farm profitability.

A study was started in 2003 to evaluate three water and nutrient management systems for tomato and watermelon production in southern Florida with regards to production, water quality, and farm income. The first system involved typical water and nutrient management practices encountered in southern Florida. The second and third systems involved soil moisture-based water table management systems with UF/IFAS recommended fertilizer rates. This report provides the data for the 2006 tomato growing season. The fall 2006 data was collected as a replacement for the fall 2005 growing season data. Due to Hurricane Wilma (October 24, 2005), the experiment was seriously compromised and repeated in fall 2006.

Experiment Design

A study was designed to evaluate the differences between specific nutrient and irrigation combinations applied to watermelon and tomato. Nutrient management treatment involved two rates, Grower and IFAS. The Grower's treatment received average fertilizer rates computed from a water and nutrient management survey conducted in southwest Florida. The survey collected the water management and fertilizer application rates (N-P-K) data from tomato and watermelon growers in southwest Florida who use seepage irrigation on plastic mulched crops. The IFAS treatment includes applying the fertilizer rates that are recommended by the Institute of Food and Agricultural Sciences (IFAS). While recommended N application rates are constant from season to season, P application rates are based on the soil test. Table 1 shows the actual rates applied to the two fertilizer treatments for the fall 2006 tomato crop.

Nutrient analysis of soil samples taken before the installation of beds revealed that phosphorus concentrations were adequate according to IFAS recommendations. Therefore, phosphorus was not applied to the IFAS plots. The IFAS treatment was divided between two methods of irrigation, seepage (furrow) irrigation and sub-surface drip irrigation (to maintain water table). Irrigation management for both IFAS treatments was based on measured soil moisture content within the raised crop beds. The moisture content for the IFAS treatments was based on maintaining optimum soil moisture level (8 – 12 %). Water table beneath the IFAS treatment fields were managed to maintain an average soil moisture of 8-12%. The irrigation management for the Grower treatments was based on the water and nutrient management survey which revealed that growers maintained soil moisture levels within the range of 16 – 20 % (volumetric). Therefore, for Grower treatment, water table was raised to maintain the high soil moisture (16-20%).

The three treatments in this study were evaluated for fruit yield, soil nutrient, and groundwater quality. Each treatment had two replications. The field (figure 1) was divided into six plots and each plot was randomly assigned one of the three treatment combinations; Grower with seepage irrigation (Grower), IFAS with seepage irrigation (IFAS – Seepage) and IFAS with subsurface drip irrigation (IFAS-Drip). Fruit yield was determined using the weight of fruit removed from sample plots within each treatment plot. The sample plot area for horticultural assessment considered the healthiest plants within a bed (figure 2). The sample area includes six sub-plots, each having ten adjacent tomato plants. The sub-plots were placed to the north and south of each treatment plot. Soil solution N was determined from extracting samples on weekly basis from a suction lysimeters installed in the crop beds of each plot. Groundwater quality was determined from water samples collected from groundwater wells located at three points above the

spodic layer (shallow wells) and two points beneath the spodic layer (deep wells). Water quality samples collected from these wells were sent to a lab for analysis.

Cultural Practices

Irrigation for crop bed development in each plot was started on July 28, 2006. Crop beds were installed on July 31 - August 1, 2006. The fertilizer rates shown in Table 1 were applied to the three treatments. The fumigant Telone C35 was also infused to manage the presence of nematodes, weeds and other soil borne diseases. Tomato plants were transplanted on the plastic mulch beds during September 5 – 6 period. Right after planting, plants were immediately watered to promote plant establishment. Transplants were watered in with plain water, using water wagons, up to three day after the day plants were transplanted. The water table in each plot was managed to maintain the moisture content within the range 16 – 20% for two to three weeks; this allowed transplant establishment. After plant establishment, moisture treatments were applied to appropriate plots. Plants were monitored regularly for disease such as Phythium and Fusarium. Fungicides and/or herbicides were applied on a weekly basis to control the growth of fungi and weeds within each plot. Tomato plants were staked during September 20-25 period. Plants were pruned and tied on September 29, October 13 and November 1. Tomatoes were harvested on November 29, December 13 and December 21.

Monitoring Data

The tomato yield data for each treatment are shown in Figure 3. For fall 2006 season, IFAS Seepage 2 (IFAS Seepage treatment, replication 2) produced the greatest yield of 34594 lbs/acre and the IFAS_Drip 2 (IFAS Drip treatment, replication 2) treatment produced the smallest yield of 22300 lbs/acre for the first harvest. The second harvest data showed that IFAS_Seepage 2 treatment had the greatest yield while the IFAS_Seepage 1 treatment produced the smallest yield. The third harvest resulted in the Grower 1 treatment (Grower treatment, replication 1) producing the greatest yield while the IFAS Seepage 1 treatment producing the smallest yield, 40081 lbs/acre and 22954 lbs/acre respectively. On average, Grower treatment produced the highest yield (122271 lbs/acre) while the IFAS_Drip treatment produced the lowest yield (104326 lbs/acre).

Figure 4 compares the concentration of soil nitrogen as nitrate + nitrite ($\text{NO}_x\text{-N}$) and ammonium ($\text{NH}_3\text{-N}$) from each treatment. The Grower treatment had the highest concentrations of $\text{NO}_x\text{-N}$ (182 mg/l) and $\text{NH}_3\text{-N}$ (14 mg/l) while the IFAS_Seepage treatment had the lowest concentration of $\text{NO}_x\text{-N}$ (64 mg/l) and $\text{NH}_3\text{-N}$ (0.55 mg/l).

Figure 5 shows the Ortho P, total phosphorus (TP), $\text{NO}_x\text{-N}$, $\text{NH}_3\text{-N}$, and total Kjeldahl nitrogen (TKN) concentrations in the shallow (above spodic layer) and deep (below spodic layer) groundwater monitoring wells. For shallow groundwater wells, Grower treatment had the highest levels of Ortho P and TP with concentrations of 5664 $\mu\text{g/L}$ and 5044 $\mu\text{g/L}$, respectively while for IFAS_Drip treatment the concentrations were 1758 $\mu\text{g/L}$ and 1729 $\mu\text{g/L}$, respectively. The Grower treatment showed the highest levels of $\text{NO}_x\text{-N}$, $\text{NH}_3\text{-N}$ and TKN with concentrations of 29 mg/L, 11 mg/L and 12 mg/L, respectively in the shallow groundwater wells while the IFAS_Seepage treatment had the lowest levels of $\text{NH}_3\text{-N}$ and TKN with concentrations of 2.4 mg/L and 3.1 mg/L, respectively. The IFAS_Drip had the lowest concentrations of $\text{NO}_x\text{-N}$ in the shallow groundwater with a concentration of 7.3 mg/L.

Results for the deep groundwater samples from the three treatment showed that similar to the shallow groundwater results, the Grower treatment had the highest levels of Ortho P and TP with concentrations of 3401 µg/L and 2985 µg/L, respectively. However, the IFAS Drip treatment had the lowest levels of Ortho P while the IFAS_Seepage treatment had the lowest levels of TP with concentrations of 1468 µg/L and 1386 µg/L, respectively. The Grower treatment had the highest levels of NO_x-N, NH₃-N and TKN with concentrations of 14 mg/L, 2.5 mg/L and 3.7 mg/L, respectively. The IFAS_Seepage treatment had the lowest levels of NH₃-N and TKN, while the IFAS_Drip treatment had the lowest level of NO_x-N with concentrations of 1.0 mg/L, 2.2 mg/L and 5.8 mg/L, respectively.

As expected, the Grower treatment had a moisture level higher than those for IFAS_Seepage and IFAS_Drip treatments with values of 17%, 11% and 15%, respectively (figure 6). On average, the water table below the Grower treatment was higher than the IFAS Seepage treatment (figure 7). The seasonal irrigation water use was higher for Grower treatment (1105943 gal) than IFAS_Seepage (969306 gal) and IFAS_Drip (1062809 gal) treatments (figure 8).

The rainfall, potential evapotranspiration (ET), and temperature data for the season is shown in Figure 9. The weather data was recorded at the FAWN weather station located next to the experimental site at the SWFREC, UF/IFAS, Immokalee.

Extension Activities

The fall 2006 crop season data (rainfall, evapotranspiration, yield, moisture content and depth to water table) were compiled and presented to vegetable growers, allied industry, and state agencies (total attendees > 25) at the Fall Vegetable Field Day held at the South West Florida Research and Education Center (SWFREC), Immokalee.

Study Progress

Fall 2006 concluded the experimental part of the study. The data are being currently being analyzed using statistical techniques. A refereed journal article on the effect of water and nutrient management on watermelon yield data from this study was submitted in 2006. The article has been accepted for publication and is scheduled to be published in June-July 2007 issue of *HortTechnology*. At least two more journal articles are under preparation for submission to publish the water use and water quality aspect of the study.

Table 1. Fertilizer rates applied to Grower and IFAS treatments for the fall 2006 tomato growing season.

	Treatment	
Nutrient	Grower	IFAS
Nitrogen	373 lbs/ac.	200 lbs/ac.
Phosphorus	162 lbs/ac.	0 lbs/ac.
Potassium	673 lbs/ac.	225 lbs/ac.

Plot1 Grower 1	Plot2 IFAS-drip 1
Plot3 IFAS 1	Plot4 Grower 2
Plot5 IFAS-drip 2	Plot6 IFAS 2

Figure 1. Irrigation layout for each treatment for the experiment.

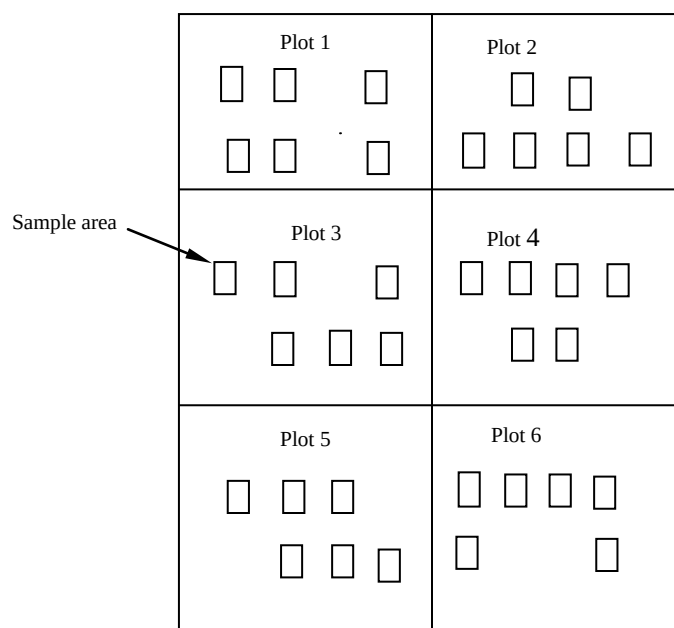


Figure 2. Example of plot distribution for tomato yield sampling within each treatment plot.

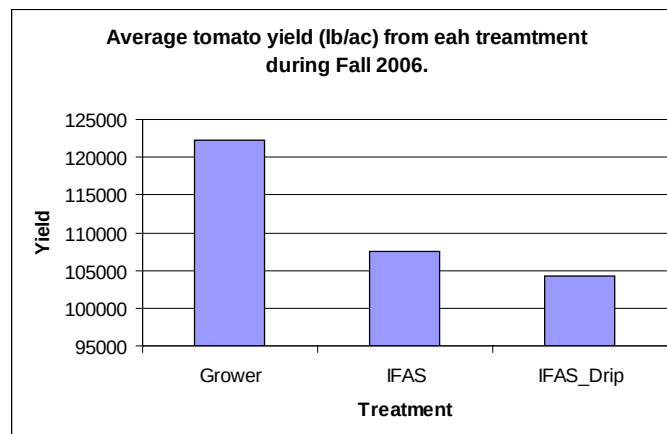
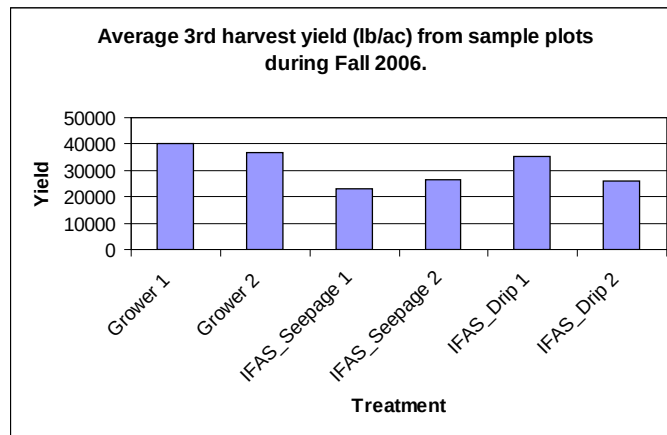
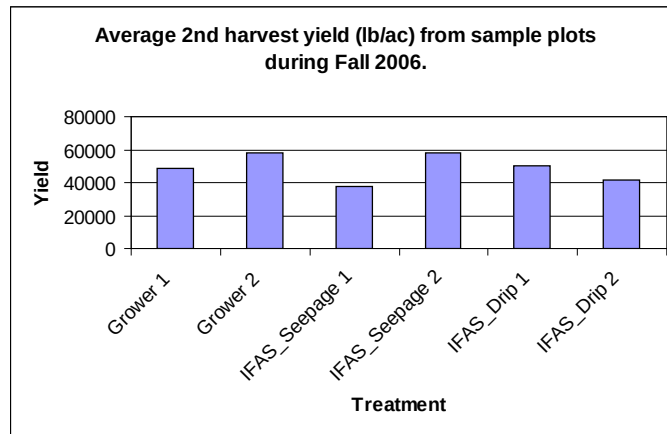
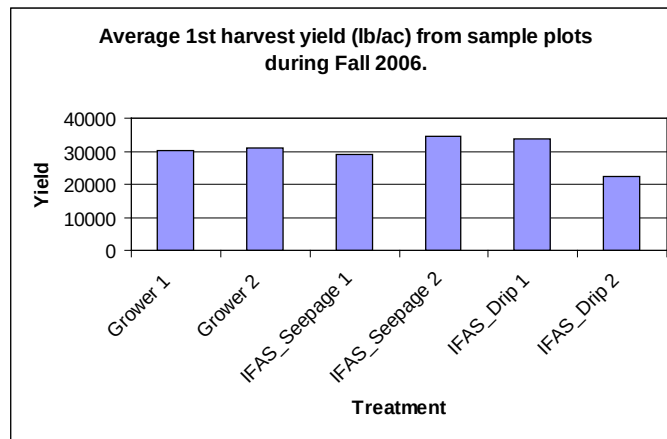


Figure 3. Yield (lbs/ac.) of tomatoes, by treatment for the crop season fall 2006.

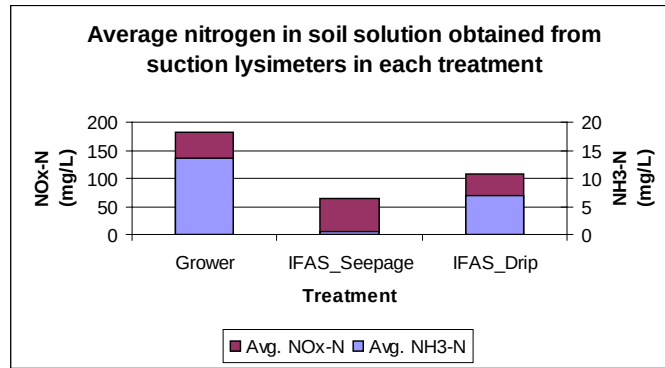


Figure 4. Average soil solution N ($\text{NH}_3\text{-N}$ and $\text{NO}_x\text{-N}$) concentration data for the fall 2006 season.

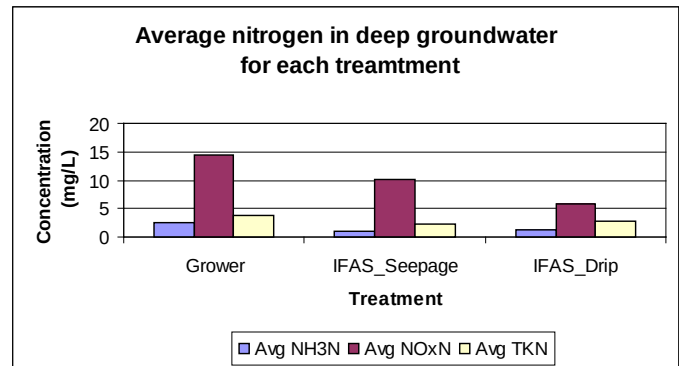
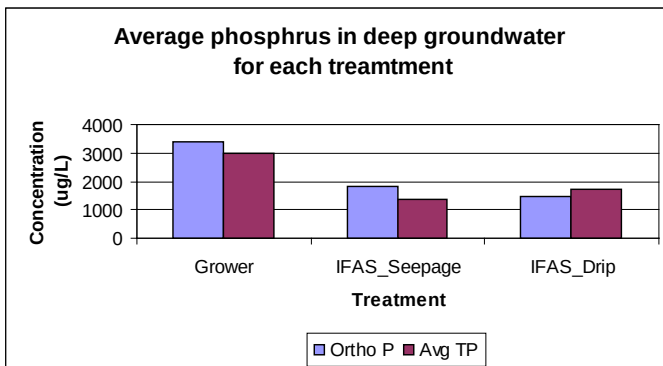
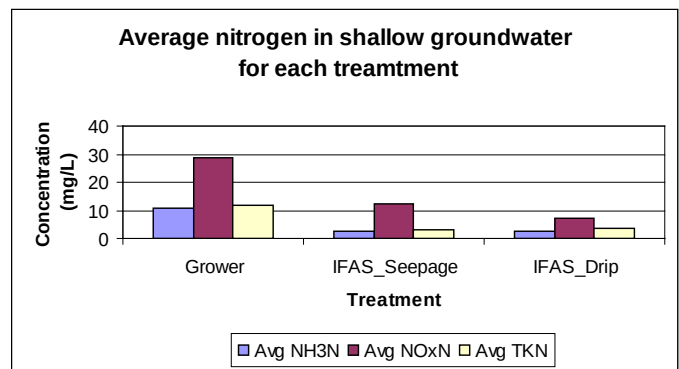
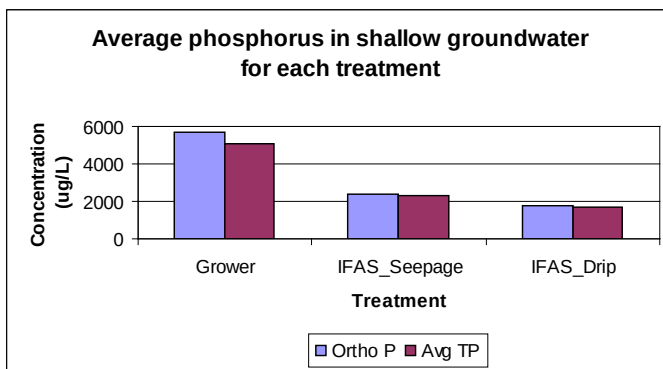


Figure 5. Average groundwater N and P concentration data for the Fall 2006 season. Shallow groundwater samples were taken from depths above the spodic layer and deep groundwater were taken from depths below the spodic layer.

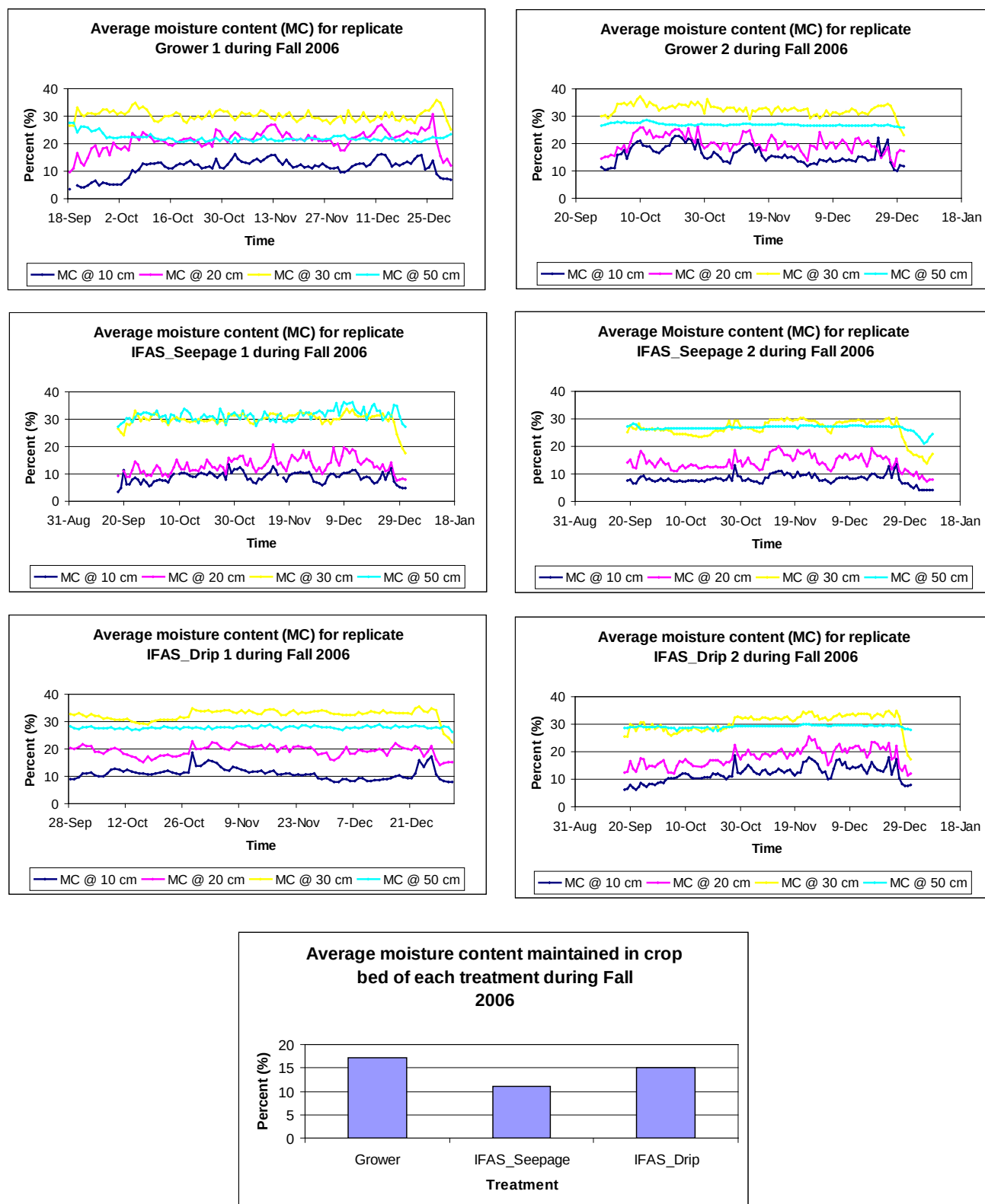


Figure 6. Daily and seasonal average soil moisture content (MC) data for the fall 2006 tomato growing season.

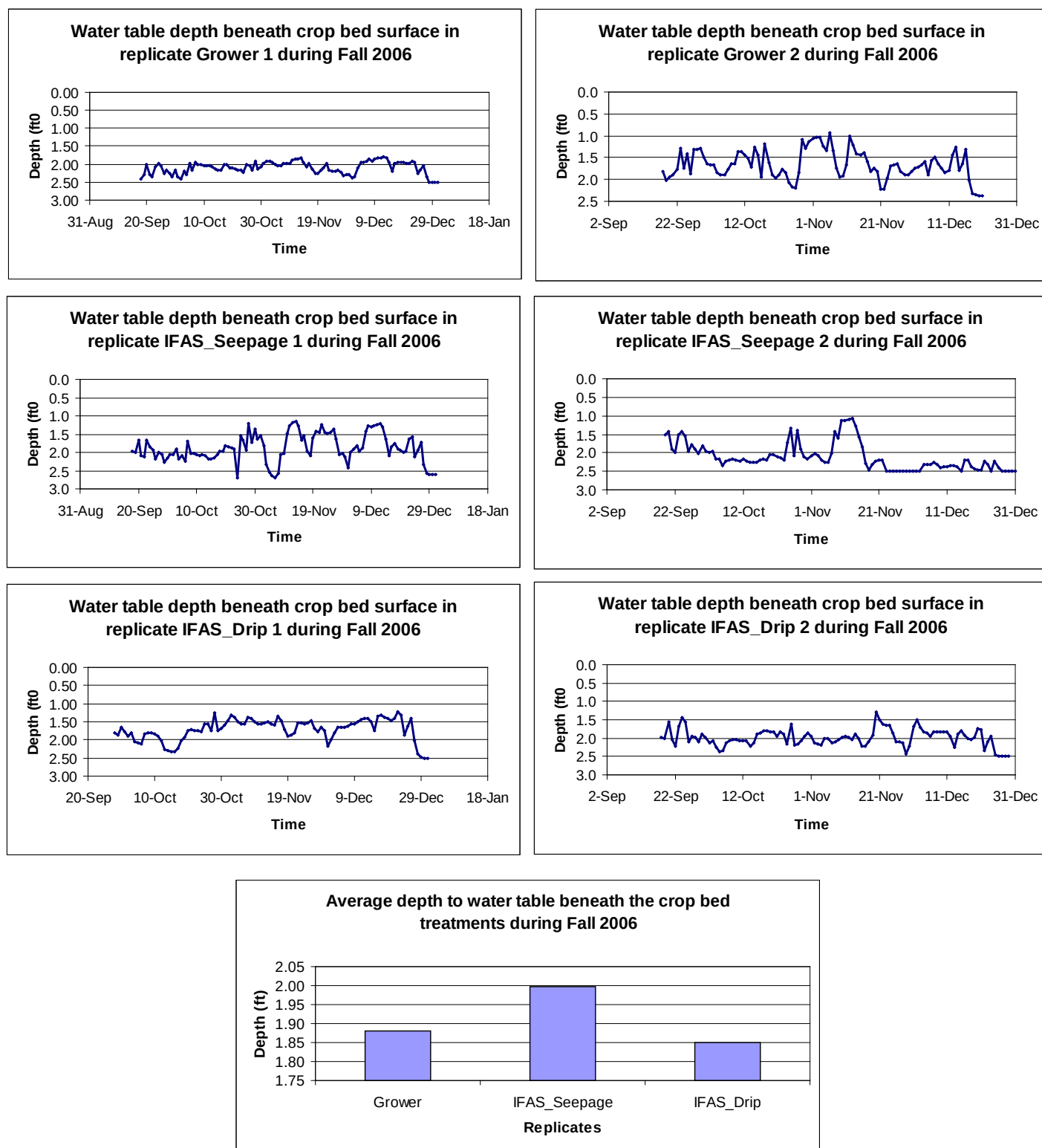


Figure 7. Daily and seasonal average groundwater table depth data for the fall 2006 growing season.

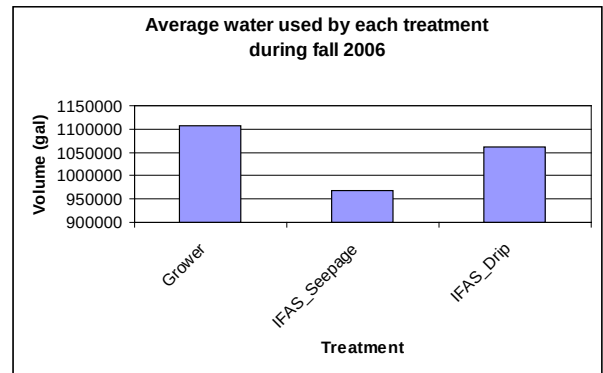
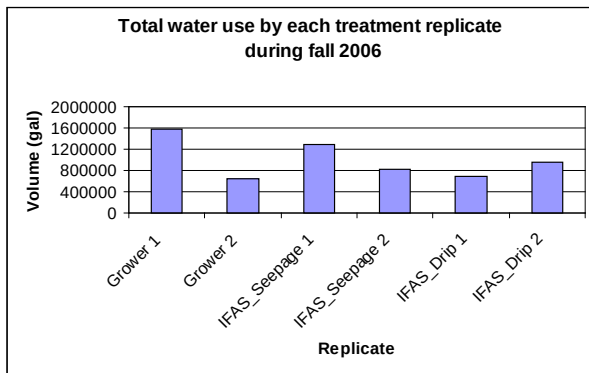


Figure 8. Water use (gal) for the three treatments for the fall 2006 growing season.

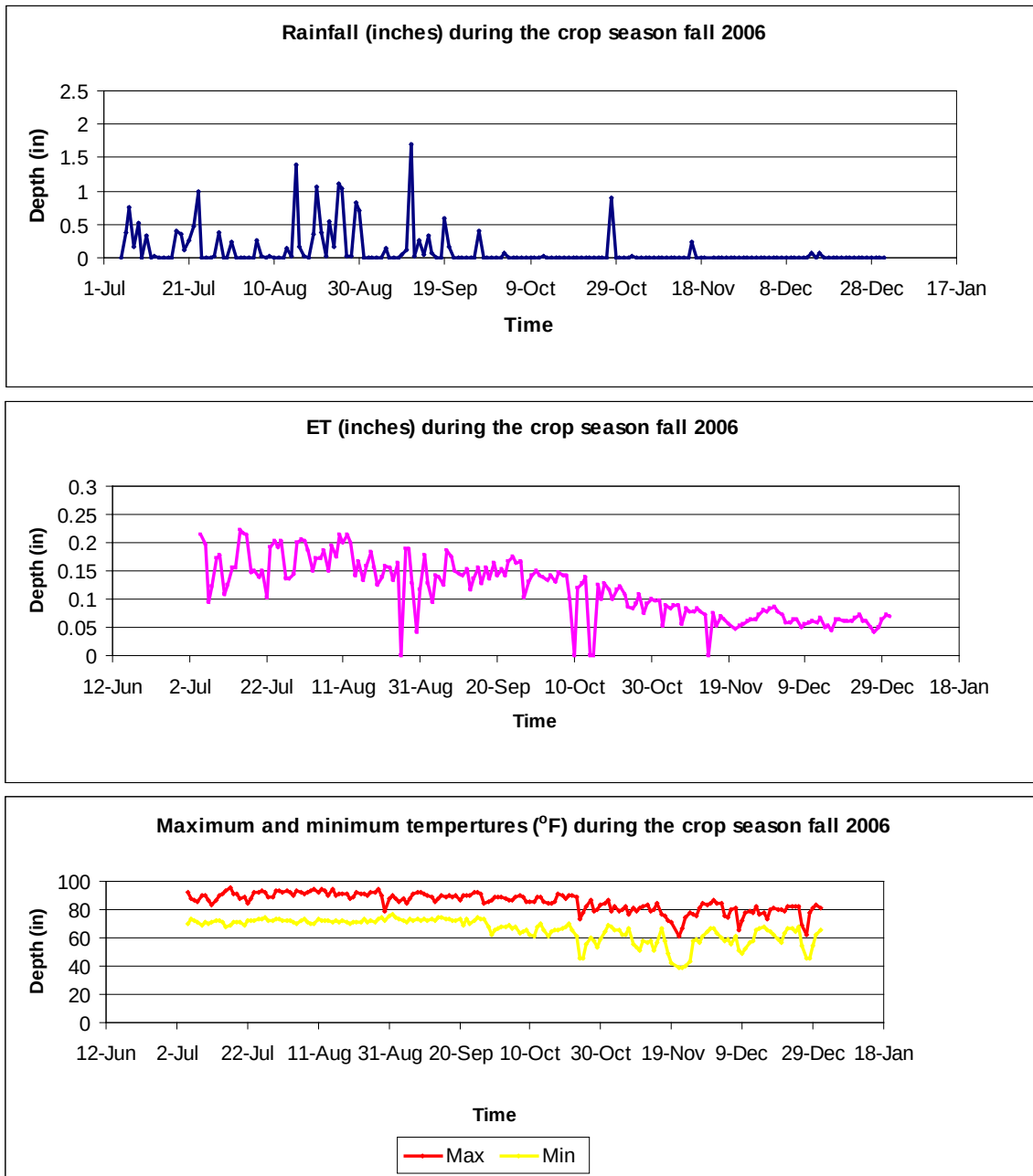


Figure 9. Rainfall, potential evapotranspiration (ET), and temperature data for the fall 2006 growing season.